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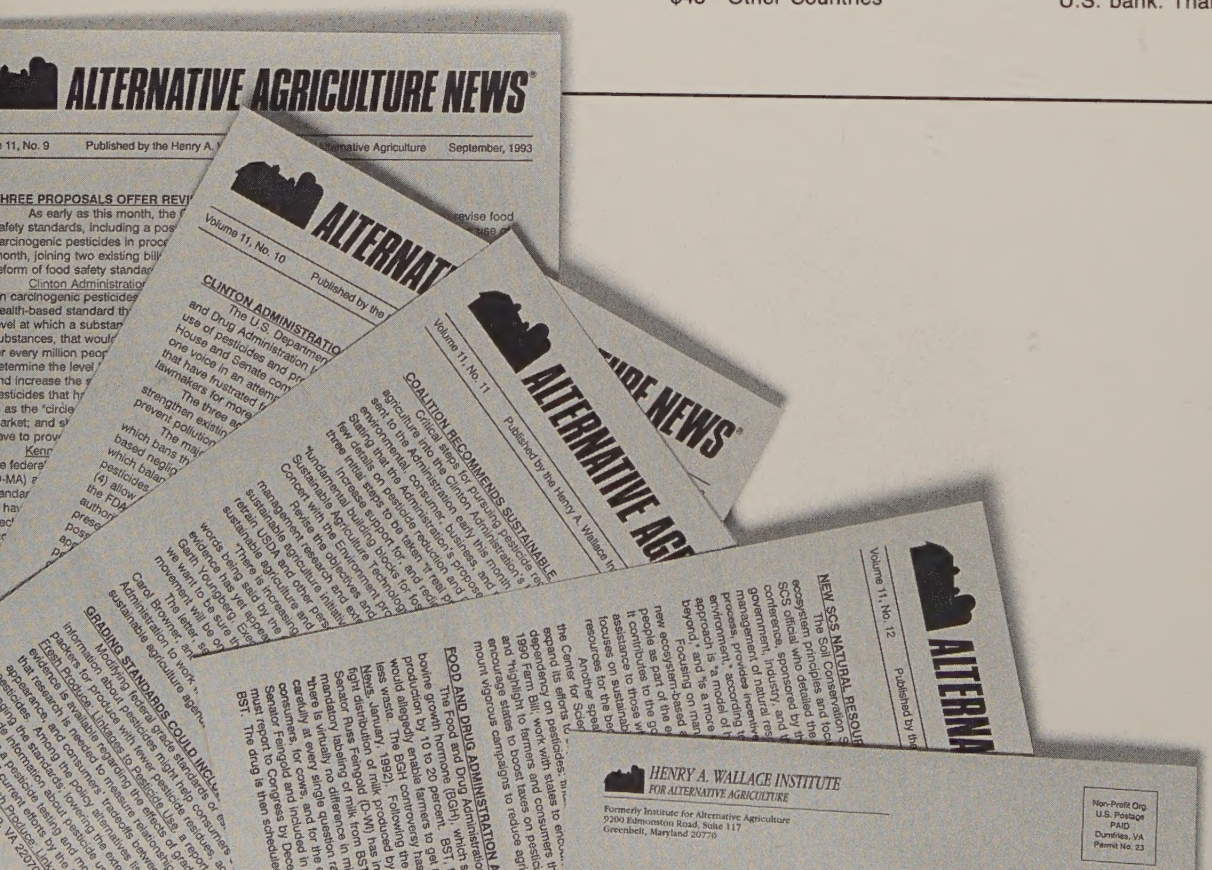

AMERICAN JOURNAL OF ALTERNATIVE AGRICULTURE®

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TABLE OF CONTENTS

146 ***Opinion*—Organic farming and social context: A challenge for us all** • Laura B. Delind

148 **Second-level integrated pest management in commercial apple orchards** • Ronald J. Prokopy, Daniel R. Cooley, Wesley R. Autio, and William M. Coli

157 **Mycorrhizae in sustainable agriculture. I. Effects on seed yield and soil aggregation** • Gabor J. Bethlenfalvay and José-Miguel Barea

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The cover photo shows IPM field supervisor Jennifer Mason examining apple leaves for pests and beneficials to assess the effects of second-level IPM practices in Massachusetts apple orchards. Photo provided by Ronald Prokopy, Department of Entomology, University of Massachusetts, Amherst, MA.

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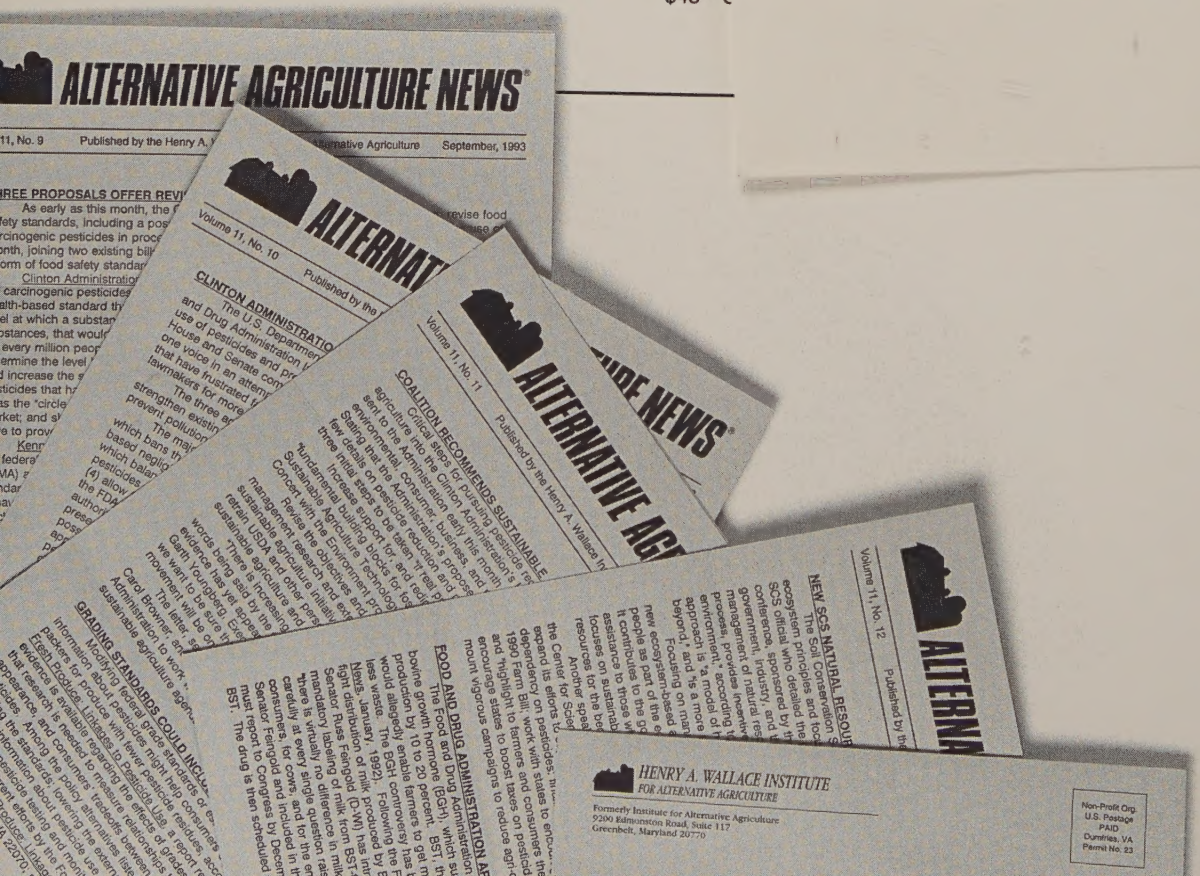

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146 ***Opinion*—Organic farming and social context: A challenge for us all** • Laura B. Delind

148 **Second-level integrated pest management in commercial apple orchards** • Ronald J. Prokopy, Daniel R. Cooley, Wesley R. Autio, and William M. Coli

157 **Mycorrhizae in sustainable agriculture. I. Effects on seed yield and soil aggregation** • Gabor J. Bethlenfalvay and José-Miguel Barea

162 **Reduced chemical input cropping systems in the southeastern United States. II. Effects of moderate rates of N fertilizer and herbicides, tillage, and delayed cover crop plow-down on crop yields** • Larry D. King

171 **Grain yield response of corn, soybean, and oat grown in a strip intercropping system** • Mohammadreza Ghaffarzadeh, Fernando García Préchac, and Richard M. Cruse

178 **Energy and economic savings from the use of legume cover crops in Virginia corn production** • D.R. Ess, D.H. Vaughan, J.M. Luna, and P.G. Sullivan

186 **Communicating between farmers and scientists: A story about stories** • Connie and Doc Hatfield, Preston and Wanda Boop, and Ray D. William

Departments

Institute News—156 • Resources—177 • Book Reviews—187 • Upcoming Events—191

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OPINION

Organic farming and social context: A challenge for us all

Laura B. DeLind

The value of organic and low-chemical agriculture has become increasingly apparent to many small and family-scale farmers over the last decade. Such practices regenerate the soil, reduce environmental pollution, lower production costs, and produce quality foods that can be sold at a premium. Thus, for many growers, alternative farm methods appear to combine the best of two worlds — a reliable way to make a living and a responsible way to produce good food. Yet, bound as they are to the conventional, market-based production paradigm, this reliability and responsibility may be more imagined than real.

How can this be? To begin, an exclusive or premium product requires an exclusive or specialized market. One Michigan farmer, for example, chose to advertise his organic beef by claiming that he raised the same cattle in the same manner as those raised for the Queen of England's table. The implication was clear: for a price, we all can eat like queens. While this particular promotional ploy may be extreme, such a marketing strategy is not uncommon. But it offers little sustained opportunity for the smaller alternative producer. With sales dependent on a circumscribed target population, a specialty market can quickly collapse because of a change in vogue, in transportation costs, or in relationships among wholesalers or retailers. Likewise, the necessity of competing with other non-traditional farmers for a market niche and maintaining a competitive edge within it requires expanding one's production and marketing options or further differentiating one's products. Both options threaten to increase dependency or reduce flexibility by increasing the scale of operations and capital investment and by narrowing the range of processes and products that can be managed profitably. Capital efficiency again is positioned to replace ecological rationality.

Likewise, as alternative production techniques and products become more credible and economically attractive, they are adopted by large-scale commercial producers and standardized through volume contracts and vertical coordination, if not integration. As Kirschenmann et al. (1993, p. 19) have observed: "Investment bankers from America's largest firms now prowl organic trade shows eager to incorporate emerging organic manufacturers into larger food multinational or venture capital driven marketing plays." Stated differently, agribusiness has shown itself fully capable of adopting environmentally respectable, even organic, methods and products when they can be privatized or when not adopting them proves unprofitable. Given the current structure of the industry, smaller, alternative farmers will not find any long-term economic security within so-called free-market competition.

If producing organic products for specialty markets is not a reliable way to make a living, is it nevertheless a responsible way to produce good food? To answer "yes" would be to argue that what is good for the environment is good for society at large. Can we really work toward sustainability without simultaneously addressing deep and pervasive social, economic and political inequities? This is a major debate within the sustainable agriculture and sustainable development literature. It alerts us to two troubling issues that have received only limited attention in alternative agriculture in the U.S. First, why should only those individuals with deep pockets have access to good food? Second, why should good food be a "specialty item" — something relegated to a market niche in the first place?

Certainly, a partial answer hinges on the production paradigm that many alternative producers continue to share, and are encouraged to share, with the agriculture/food industry as a whole. Michigan's Assistant Director of Agriculture, for instance, publicly advised the state's organic producers to pursue niche markets. In this paradigm, food is a market commodity. It is viewed as a product grown to satisfy a niche within the now global marketplace. Its primary purpose is to feed capital and expand profit. Only secondarily is it grown to feed people and expand their creative capabilities. Given this orientation, human relationships are simplified to a single dimension (their potential for market-based consumption) and the value of a relationship equates with the value of a market exchange. As one midwestern organic farmer unwittingly summarized, "Everybody needs business cards" and don't forget to "always treat friends and neighbors as potential customers."

Those who can't (or won't) interact along this purely "practical" dimension can easily be dismissed and devalued. Such a perspective makes it possible to ignore the

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rights of significant portions of the population — the poor, the hungry, agricultural labor, women, racial and ethnic minorities. It also dehumanizes or sanitizes what otherwise would be complex, "messy" and meaningful human and ethical considerations. As a result, it is possible to sidestep or define out of existence issues of public rights, public access, public participation and accountability. It becomes both possible and desirable to replace the "common good" with a cost-benefit analysis.

This prevalent mindset is still wedded to a system that is monocultural (in all senses of the term). And it will have the same stifling and wasteful results, whether they are obtained organically or conventionally. Within this mindset, the human experience increasingly is commoditized and torn apart, with each surviving bit molded to fit a market exchange. We can, however, envision an alternative system in which economics — production, utilization, trade — is (re)embedded in culture and (re)integrated into all the activities that define oneself, one's relationships to others, and one's social and physical place in the universe. The former requires us to ask, "What can I grow that will make me money?" and "How much can I charge for my product?" The latter permits us to ask, "What can I grow that will allow more people to eat better and become more directly involved in the food system?" and "How *little* do I need to farm in a socially and environmentally regenerative manner?"

This second set of questions uses organic or low-input production practices and technologies to address the inequities, the exploitive relationships, and the dependencies that conventional agriculture has benefitted from but has ignored. These questions imply an agriculture reunited with its social context. As Henderson (1992, p. 35) has expressed it, "Organic agriculture can never be agri-business as usual. The strength of the organic movement lies in its decentralization and regional orientation. The foundation of our growing system is stewardship of the land, long-term sustainable relationships with soil organisms, animals and our fellow human beings."

Proceeding from this alternative paradigm does not mean that producers must forgo being practical or making a living. Quite the contrary: as Kneen (1993) has noted, it means being paid fairly for the work that we do rather than defining what we do solely in terms of making money. It means directing more emphasis inward toward domestic food security than outward toward volume production and expansion of export markets. This will require that producers and eaters share the risks, rewards and responsibilities of natural resource use, food production and distribution at local and regional levels. Nonproducers will need to know where their farmers are and where they are "coming from." They will need to know how farm practices affect the health of the environment and the quality of food it supports. Farmers, in turn, will need to know where there is local hunger and where it's "coming from." Likewise, they will need to know how the lack of food and resource equity affects the health of the surrounding community and the quality of life it supports.

This "connectedness" emerges as we forge new relationships not around commodity markets but around a more locally responsive food system. Diverse institutions like community supported agriculture, producer-nonproducer cooperatives, urban gardens, farmers' markets, community land trusts, and food policy councils are components of such a system. Each gives expression to the inherent relationship between good food, good farming and community building. And "community," as Ebenreck (1992, p. 3) has so elegantly written, "is our name for the living, heartfelt and truly sustaining, mutually empowering, networks of relationships" that are basic to our species.

We can use our knowledge of organic and alternative methods of farming as a tool to decentralize and democratize our food system. This knowledge and the philosophy that underlies it constitute the collective wisdom and energy of thousands of organic and low-input farmers and activists who with little economic or institutional support have challenged conventional farming. All of us who eat, not just those who raise our food, must now extend this challenge into both the social and the economic realm of our daily lives. Otherwise, we will continue to lose the opportunities and choices that new agroenvironmental relationships can offer. They will be submerged beneath the dominant market paradigm. And, that, as niche-oriented production indicates, is no alternative at all.

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Large Hog Producers May "Cripple" Iowa Family Farms, Paper Reports

Large corporate hog producers in Iowa are not only "destroying the quality of [Iowans]' lives with intolerable odors and the threat of groundwater contamination," but also threatening eventually to "cripple the traditional backbone of Iowa agriculture, the family farm," according to a recent front-page article in *The Washington Post*. With large producers "invading the state," constructing huge facilities that "yield with assembly-line efficiency growing amounts of leaner pork...it is not just the air and water that are threatened, critics argue, but a way of life." Large corporate producers have been responsible for substantial gains made in North Carolina's pork production, and were also responsible for transforming the poultry industry, shifting its center from Iowa to Arkansas, Maryland, and Virginia. A government task force has been set up to study the environmental issues at stake, and when the state legislature convenes in January, several measures will probably be introduced to restrict the growth of large hog farms, according to the article. Iowa currently accounts for 25 percent of the nation's pork production.

Second-level integrated pest management in commercial apple orchards

Ronald J. Prokopy, Daniel R. Cooley, Wesley R. Autio, and William M. Coli

Abstract. *As historical background helpful to understanding current concepts and practices of apple pest management, we review the origin and rise of key pests of apple in North America and the evolution of approaches to their management, culminating with the concept of integrated pest management (IPM). We propose four levels of integration of orchard pest management practices. First-level IPM integrates chemically based and biologically based management tactics for a single class of pests, such as arthropods, diseases, weeds or vertebrates. Second-level IPM, the focus of our effort here, integrates multiple management tactics across all classes of pests. We describe components of second-level IPM for Massachusetts apple orchards, which are threatened each year by an exceptionally broad range of injurious pests. We illustrate the tentative advantages and shortcomings of second-level IPM using 1993 data from six commercial orchard test blocks. Our predominant approach was to use chemically based tactics for controlling arthropods, diseases and weeds early in the growing season, and afterwards to rely exclusively (for insects) or largely (for other pests) on biologically based tactics, such as cultural, behavioral, and biological controls. Compared with nearby first-level IPM blocks, insecticide use in 1993 was reduced substantially (about 30%), with only slightly more insect injury to fruit and little difference in populations of foliar insect pests. The results for mite pests and diseases were less encouraging although summer pruning significantly reduced disease injury caused by flyspeck. We discuss how second-level IPM poses special biological or operational challenges to apple pest management practitioners. The concept has merit, but refinements are necessary before it can be recommended broadly to commercial apple growers in Massachusetts as an economical and reliable alternative to first-level IPM.*

Key words: apple, integrated pest management, insects, diseases, mites, weeds, pesticides

Issues involved in achieving sustainability in agriculture reach across all commodities, but management of pests in tree fruits, in particular apple (*Malus domestica)*, is among the most demanding challenges to implementing truly sustainable practices (Merwin and Pritts, 1993). We first discuss the origin and rise of key pests of apples in North America and the evolution of approaches to apple pest management, culminating in a proposal of four progressive levels of integration of pest management practices. We focus on the second level, illustrating its benefits and shortcomings as practiced recently in several commercial apple orchards in Massachusetts.

Ronald Prokopy is Professor, Department of Entomology, Daniel Cooley is Assistant Professor, Department of Plant Pathology, Wesley Autio is Associate Professor, Department of Plant and Soil Sciences, and William Coli is Integrated Pest Management Coordinator, University of Massachusetts, Amherst, MA 01003.

Origin and Rise of Key Pests of Apple in North America

Domesticated apple trees originated in southern Eurasia (Roach, 1985). They were brought to western Europe more than two thousand years ago, and from there to North America early in the 17th century (Chapman and Lienk, 1971). During their first two centuries in North America, either apple trees were mostly free of the pests that we now consider most troublesome or the damage that such pests caused was considered acceptable (Hedrick, 1950). The calm was broken in the 19th century by a combination of events that caused serious and widespread outbreaks of many pests that currently are the most damaging in North American apple orchards.

Among arthropods, the plum curculio (*Conotrachelus nenuphar* [Herbst]), the apple maggot (*Rhagoletis pomonella* [Walsh]), the redbanded leafroller (*Argyrotaenia velutinana* [Walker]), and the tarnished plant bug (*Lygus lineolaris* [Palisot de Beauvois]) are endemic species that expanded their host range during the 19th century from native plants to introduced apples (Chapman, 1938; Bush, 1966; Chapman and Lienk, 1971). To our knowledge, no native North American arthropods have arisen during the 20th century to become such serious pests of apples. At least one major microbial pest of apples, *Erwinia amylovora* (Winslow et al.), which causes fire blight, is believed to be indigenous to North America. Apparently this pathogen expanded its host range in North America from native species to apples in the 18th century, then gradually spread to most other parts of the world (Van der Zwet and Keil, 1979). Cedar apple rust (caused by *Gymnosporagium juniperi-virginianae* [Schwein]) also moved to apples from a native American host, gradually becoming an important apple disease by the end of the 19th century.

While these endemic species were becoming pests in the 19th century, several injurious pests were introduced to North America from abroad, including codling

moth (*Cydia pomonella* [L.]), San Jose scale (*Quadraspidiotus perniciosis* [Comstock]), European red mite (*Panonychus ulmi* [Koch]), and apple scab (caused by *Venturia inaequalis* [G. Wint.]). The 20th century has seen the introduction of a few less serious arthropod pests than the three just mentioned, including the European apple sawfly (*Hoplocampa testudinea* [Klug]). Other diseases presumably evolved with the host in Eurasia, and were introduced. These include: powdery mildew, caused by *Podosphaera leucotricha* (E.S. Salmon); black rot, caused by *Botryosphaeria obtusa* (Shoemaker); white rot, caused by *Botryosphaeria dothidea* (Ces & DeNot); bitter rot, caused by *Colletotrichum gloeosporioides* (Penz. & Sacc.); sooty blotch, caused by *Gloeodes pomigena* (Colby); and flyspeck, caused by *Schizothyrium gloeosporioides* (Anx). Recognition of their importance as damaging pests in apple production in North America is likely to have resulted partly from the decreasing tolerance of blemishes on fresh fruit in commercial markets (Heald, 1926).

Evolution of Approaches to Apple Pest Management

The explosion of apple pests and the increased scale of apple production in North America in the 19th century was accompanied by a rapid rise in research and educational efforts to develop programs of apple pest management (Heald, 1926). Early programs were rooted largely in cultural forms of pest control (e.g., removal and burial of infested drops or turning hogs loose in orchards to consume infested drops), and the use of pesticides derived from plants (e.g., rotenone, ryania, and pyrethrum) or minerals (e.g., calcium arsenate, lime-sulfur, and copper sulfate). These efforts were accompanied in the early 20th century by a strong interest in promoting biological control of apple arthropod pests through conservation, augmentation, or importation of natural enemies (Allen et al., 1940). Breeding also played a role in early pest management. Some early American horticulturalists established orchards purely for seed production. Because apples are cross-pollinated, all seeds are genetically different, permitting these horticulturalists to have selected individual plants for disease tolerance as well as productivity and fruit quality.

Dramatic changes occurred in the mid-20th century with the appearance of chlorinated hydrocarbon insecticides, ethylenebisdithiocarbamate fungicides, and many other synthetic organic pesticides. From around 1945 to 1970, approaches to apple pest management changed only slightly. Pesticides were applied largely as a preventive, calendar-based system of control, irrespective of whether pests were sufficiently abundant to cause injury.

Over the same period, cold storage and then controlled atmosphere storage made it possible to store fresh fruit for several months. Before then, most apples were processed into cider, apple butter, dried apples, or other products more suitable for long-term use (Hedrick, 1950; Roach, 1985). Long-term storage affected pest management in two ways. First, postharvest rots such as blue mold (caused largely by *Penicillium expansum* [Link]), which were not a problem in processed apple products, now required chemical control. Second, fresh apples available for most of the year had to be almost blemish-free because the "eye-appeal" of fresh produce became important to consumers and marketers. As a result, fresh fruit growers strove to keep disease and insect damage far lower than in other crops. Appearance, perhaps more than yield, began to drive apple pest management programs, requiring increased applications of chemicals (Schuhmann, 1976).

Eventually, however, several orchard pests (notably spider mites) became resistant to pesticides and surged to outbreak levels. Thus, a purely pesticidal approach was not sustainable. Although environmental and economic concerns also played a role (Rajotte, 1993), pesticide resistance was perhaps the most important reason that the modern programs of integrated management of apple pests were begun in the 1970s.

Concepts of integrated pest management (IPM) are quite variable. Dover (1985) has captured the ideals of IPM well. His concept consists of the following elements:

- optimizing pest control in an ecologically and economically sound manner;
- emphasizing coordinated use of multiple tactics to enhance stable crop production;
- maintaining pest damage below injurious levels, while minimizing hazards to humans, animals, plants, and the environment.

Since the early 1970s, achievement of these ideals in apple orchards has progressed gradually. Because pesticides are toxic to some beneficial organisms, and because pests were rapidly becoming more resistant to pesticides, at first the emphasis was on improved use of chemicals against arthropods (termed "chemically dependent IPM" by Frisbie and Smith [1991] and "chemically based IPM" here). The primary intent was to use selective pesticides that allowed natural enemies of pests to survive, and to apply pesticides only when information from monitoring the weather or the first appearance or abundance of pests indicated the need for application. More recently, orchard IPM practices in some regions have been driven by other factors: unavailability of pesticides when manufacturers do not seek to renew registration; increasing fear of pesticide drift onto areas near orchards; media and public attention to perceived harmful effects of pesticides on harvested fruit; and efforts to merge the strategies and techniques of IPM with those of sustainable agriculture. The focus has begun to shift away from chemically based IPM and toward biologically based IPM (Frisbie and Smith, 1991). This involves replacing pesticides with nonpesticidal control methods such as host plant resistance, biological control, cultural control, behavioral control, and autocidal control (e.g., mass release of sterile males).

Advancing Levels of Integration in Orchard Pest Management

To help achieve the ideals of orchard IPM, Prokopy (1990) proposed a concept of progressive levels of integration, analogous to four steps of a ladder (Prokopy, 1993). Concepts developed by Geier

(1982) and Kogan (1988) underlie this stepwise approach.

- First-level IPM integrates chemically based and biologically based management tactics for a single class of pests, such as arthropods, diseases, weeds, or vertebrates.
- Second-level IPM integrates multiple management tactics across all classes of pests.
- Third-level IPM emphasizes integration of pest management approaches with the entire system of crop production on a farm, meaning that IPM practices across all classes of pests would be developed in concert with all horticultural practices (i.e., the interface of IPM with sustainable agricultural practices).
- Fourth-level IPM involves social, cultural, and political realms. It calls for blending the concerns of everyone with an interest in IPM: growers, researchers, extension personnel, private consultants, industry, product distributors, neighbors of growers, environmentalists, and regulatory agencies.

Progress under first-level IPM for apple orchards has been reported for Massachusetts and several other North American locations (reviewed in Whalon and Croft, 1984; Gadoury, 1993; Prokopy and Croft, 1994), and in other parts of the world (Gupta, 1985; Solomon, 1987; Blommers, 1994).

Here, we describe components of second-level IPM for Massachusetts apple orchards. We illustrate progress toward achieving second-level IPM goals using 1993 data from six commercial test blocks in which second-level IPM practices were partially employed in 1991 and 1992, and more fully employed in 1993. For comparison, we also give 1993 data from six adjacent first-level IPM control blocks.

On completion of our pilot project on second-level IPM in 1994, we will have four years of extensive data on pest-caused fruit injuries and the abundance of pests and beneficial arthropods in these six test and six control blocks. These data, with economic cost/benefit analyses, will be presented and discussed fully in a forthcoming article. Our intent here is to focus on concepts and approaches, with the 1993 data used only as tentative illustrations of the advantages and shortcomings of second-level IPM.

Our predominant approach to second-level IPM was to use chemically based tactics for arthropod, disease, and weed control during the first part of the growing season (to early June for arthropods and weeds, and to early July for diseases). After that, we relied largely (although not exclusively) on biologically based tactics. We believed that relying more on biologically based tactics during the second part of the season would maximize the buildup of beneficial natural enemies of arthropod pests, reduce selection pressure on pests to develop resistance to pesticides, and minimize the amount of pesticide residue on the fruit at harvest.

Because several native pests have expanded their host ranges onto apple, and because apple has many pests introduced from abroad, apple orchards in Massachusetts and other parts of the Northeast are threatened every year by perhaps the greatest variety of fruit and foliar pests in the world. Almost all fruit of unattended apple trees in Massachusetts is damaged annually by at least one insect species or disease (Prokopy, 1991). Therefore, we realized from the beginning that relying largely on biologically based tactics during the second part of the growing season might cause unacceptable levels of injury by certain pests.

Because the focus of second-level IPM is on fullest possible integration of management approaches for all classes of pests, we made a special effort to anticipate both the detrimental and the beneficial effects that actions against one class of pests might have on another class. For example, we sought to minimize the negative impact of fungicides on natural enemies of arthropod pests, particularly on predaceous mites that feed on spider mites. Thus, we sought to minimize use of the fungicides benomyl and mancozeb, which are known to harm predaceous phytoseiid mites (Croft, 1990). Although the specifics in apple orchards remain unclear, there is evidence that entomophagous fungi useful in biocontrol of arthropods may be inhibited by fungicides (Tedders, 1981; Loria et al., 1983), and that eliminating fungicides from an orchard allows biocontrol of mites (Bower et al., 1993; Cooley et al., 1994).

Similarly, we sought to accentuate practices such as summer pruning of apple trees, which in Massachusetts not only increases the fraction of the crop that is harvestable before fruit drop (Autio and Greene, 1990) but also might reduce establishment of summer disease inoculum by lowering humidity in the tree canopy. Summer pruning also might reduce populations of such insect pests as aphids and leafminers by removing watersprouts, which these pests infest.

Components of Second-level IPM for Massachusetts Orchards

Arthropods

The principal fruit-damaging arthropod pests on apple trees active from bud break until mid-June include tarnished plant bug, European apple sawfly, plum curculio, green fruitworms (*Orthosia* spp.) and first generations of San Jose scale, redbanded leafroller, oblique-banded leafroller (*Choristoneura rosaceana* [Harris]), lesser appleworm (*Grapholitha prunivora* Walker), and codling moth. The principal foliar-damaging arthropods active during this time include first generations of *Phyllonorycter* leafminers, the leafhopper *Typhlocyba pomaria* McAtee, and spider mites, particularly European red mite.

We aimed to control these early-season pests with pesticides, as no other effective controls have been developed. Whether an application was needed, and if so its optimal timing, was based on monitoring the abundance of adults using visual traps (tarnished plant bug, European apple sawfly, leafminers) and direct observation of larvae (fruitworms, leafrollers, leafhoppers, leafminers), overwintering eggs (European red mite), or egglaying scars (plum curculio) (Prokopy and Croft, 1994). Codling moth, lesser appleworm and San Jose scale were not monitored, because no pheromone traps or other reliable methods were available for accurately predicting injurious population levels of these adults in Massachusetts orchards. The pesticides used included superior oil (against overwintering European red mite eggs and overwintering San Jose scale), diflubenzuron (experimental use permit against

leafminers), endosulfan (against leafhoppers), and phosmet or azinphosmethyl (against all other arthropods).

From mid-June onward, the principal fruit-damaging arthropods included apple maggot and summer generations of codling moth, lesser appleworm, leafrollers, and San Jose scale. The principal foliar-damaging arthropods were apple aphids (*Aphis pomi* De Geer), spirea aphids (*Aphis spiraecola* Patch), woolly apple aphids (*Erisoma lanigerum* [Hausmann]), rose leafhoppers (*Edwardsiana rosae* [L.]), and summer generations of spider mites, leafhoppers, and leafminers. To control apple maggot, we used 8-cm red spherical sticky-coated traps (Tangletrap™). Each trap was baited with one polyethylene vial containing the synthetic fruit attractant butyl hexanoate (release rate = 500 µg/hr) and one semipermeable membrane containing the synthetic food attractant ammonium acetate (Consep Membranes Inc., Bend, Oregon). In late June, traps were placed 5 m apart on perimeter apple trees to intercept adults entering orchard blocks from neighboring abandoned trees up to 2 km away. They were cleaned and their sticky coating renewed (if needed) every 2 weeks until harvest. To control summer generations of codling moth and lesser appleworm, we cut down all unsprayed apple and pear trees, the primary hosts of these pests, within 100 m of the orchard block perimeter to discourage females from entering. Codling moth females rarely travel more than about 100 m under climatic conditions similar to those in Massachusetts (Wildbolz and Baggiolini, 1959).

Following harvest, drops were removed to prevent apple maggot, codling moth and lesser appleworm from building up within the orchard from infested dropped fruit. To reduce the proportion of fruit dropping before harvest, test blocks were pruned in July and (where needed) root pruned in May. Both practices have the added benefit of removing or reducing tree vegetative growth, thereby permitting better air flow through the tree canopy and better penetration of needed pesticide. No direct action was planned against leafrollers, foliar pests, or nymphs of San Jose scale. We anticipated that these pests would be controlled by the buildup of their natural enemies in the absence of insecticides or acaricides after mid-June. We sowed a blend of seeds of four genera of broadleaf plants (*Plantago*, *Trifolium*, *Lychnis*, and *Lolium*) beneath the trees in half of each test block in spring 1992. These species are favored by two-spotted spider mites and predaceous *Amblyseius fallacis* (Garman) (Coli et al., 1994). Our intent was to have these plants firmly established by 1994 to provide a reservoir of predaceous mites for colonizing the orchard trees.

Diseases

The principal disease of apple trees from bud break until mid-June is apple scab. William E. MacHardy (private communication) has proposed leaf shredding and promoting leaf decomposition over winter to reduce scab inoculum in fallen apple leaves, thereby reducing the need for fungicide treatments. However, our preliminary tests showed that from 20% to 30% of fallen apple leaves in commercial orchards remain untouched by conventional mowing or shredding equipment. With no other effective controls available, we relied on optimally timed fungicide sprays. We assessed the potential ascospore dose (Gadoury and MacHardy, 1986) and ascospore morphological maturity (Skolnik, 1969, modified by Gadoury, 1993) to determine when the first fungicide treatment was needed, and afterwards recommended a fungicide application approximately every 10 days until the risk of infection passed. We recommended combining a demethylation-inhibiting fungicide, such as fenarimol or myclobutanil, with a protectant fungicide, such as mancozeb.

From mid-June onward, the diseases of primary concern are flyspeck and sooty blotch. To manage these diseases, we prescribed fungicide applications until early July. In spite of nontarget effects, we recommended a minimum-use program of benomyl and mancozeb as the most effective way to control summer diseases. To reduce humidity within the canopy, we recommended summer pruning in vigorously growing trees (Autio and Greene, 1990; Cooley et al., 1992), augmented by mowing. This also was intended to promote earlier and more extensive fruit coloration, and to provide integration of a disease control, a horticultural and an insect management practice by allowing earlier harvest and reduced chance of preharvest fruit abscission. As mentioned previously, populations of apple maggot and other insects can develop from dropped fruit.

Weeds

Excessive growth of grasses or broadleaf weeds beneath the canopy of apple trees can reduce the availability of water and nutrients to trees and raise the humidity. High humidity favors the development of disease organisms. To alleviate these effects, areas beneath tree canopies not sown with the mixture of broadleaf species were treated in May with the herbicide glyphosate. Alleyways between the tree rows were mowed at least once per month, as were areas beneath trees during August.

Vertebrate pests

Restricting the growth of orchard floor vegetation and removing drops after harvest were intended to have the added benefit of reducing the population of damaging voles. Where birds caused fruit injury, they were repelled by Scare-Eye™ balloons (Prokopy, 1991) hung 40 m apart on poles within orchard blocks. Where deer were eating more than a few developing buds, they were subsequently repelled by hanging bars of soap (Cashmere Bouquet™) on perimeter trees.

Characteristics and Sampling of Second-level IPM (Test) and First-level IPM (Control) Blocks

Test blocks were from 2 to 4 ha. Most were bordered on two sides by woods, on one side by an open field, and on one side by an adjacent block of apple trees (2 to 4 ha) that served as a control block managed by the same grower using first-level IPM methods. Test and control blocks consisted primarily of 'McIntosh', 'Cortland', and 'Delicious' cultivars on M.26 or M.7 rootstock. All blocks bore a moderate to heavy crop of fruit in 1993.

Each block was monitored for arthropod pest abundance or injury weekly from early April (the beginning of the silver tip stage of bud development) to mid-June, and afterwards every second week until

harvest in September. Each block received five white sticky-coated rectangle traps hung at knee height for monitoring tarnished plant bug adults, five white sticky-coated rectangle traps hung at head height for monitoring European apple sawfly adults, five red sticky-coated rectangle traps stapled to the tree trunks for monitoring leafminer adults, and eight red sticky-coated sphere traps (unbaited) hung at head height for monitoring apple maggot adults. One monitoring trap of each type was placed about 5 m inward from each corner of each block, with the remainder placed near the center of the block. We recommended an insecticide application in second-level test blocks if trap captures exceeded recommended threshold levels (Prokopy et al., 1993). The apple maggot traps were used only to monitor the penetration of apple maggot flies into the block interior. To estimate the amount of insect-caused fruit injury and the abundance of foliar-feeding pests and predators of pests, on each sampling date we sampled 20 trees per block in an X pattern across the block. Thirty fruits, 10 shoot terminals, and 10 fruit cluster leaves were sampled per tree. In each case, we recorded the proportion with or without the arthropod in question. To sample abundance of predaceous spiders, we jarred three limbs per tree over a 50 by 50-cm framed cloth. We present data on the proportion of arthropod-injured fruit from samples taken at harvest and the proportion of terminals or leaves inhabited by foliar-associated arthropods, averaged over the activity period of each species.

Similarly, diseases were monitored weekly from the beginning of the silver tip stage of bud development to mid-June, and afterwards every second week until harvest in September. This monitoring was combined with the insect monitoring described above. The effects of summer pruning were assessed by leaving at least 10 trees unpruned in each test block. In early September, fruits from 10 pruned and 10 unpruned trees per block were harvested, six fruits from each of four quadrants inside the tree. After cold storage for 45 days, these fruits were analyzed for flyspeck incidence.

During 1993, our sampling of orchard weed growth was not yet sufficiently frequent and detailed for us to report impacts on mite predators. Also, because only two of the six orchards had damaging populations of either voles, birds, or deer, we do not report the data on these pests.

Results for 1993

Until mid-June, the same amount of insecticide was applied against fruit-injuring insects in second-level IPM test blocks as in first-level IPM control blocks: means of 2.7 dosage equivalents and 3.3 application events (Table 1). During this period, slightly more fungicide was applied in test blocks than in control blocks: means of 5.3 vs. 4.8 dosage equivalents, and 5.9 vs. 5.5 application events (Table 1). Combined injury on harvest fruit samples by insects causing damage until mid-June (plant bug, sawfly, plum curculio, fruitworms) averaged slightly but not significantly greater in test blocks than in control blocks (7.4 vs. 6.7%) (Table 2). Almost all injury in both types of blocks was caused by tarnished

Table 1. Mean dosage equivalents[1] of pesticide used and mean number of pesticide application events against fruit and foliar pests in six second-level IPM test blocks and six first-level IPM control blocks in 1993.

Pesticide application	Type of Block	Fruit arthropods		Fruit diseases		Foliar pests			
		Before mid-June	After mid-June	Before mid-June	After mid-June	Mites	Leafminers	Leafhoppers	Aphids
Dosage equivalents	Test	2.7	0.0	5.3	1.8	2.4	0.2	0.2	0.0
	Control	2.7	1.6	4.8	2.8	2.2	0.0	0.2	0.0
Application events	Test	3.3	0.0	5.9	2.5	3.3	0.2	0.3	0.0
	Control	3.3	2.2	5.5	3.2	3.4	0.0	0.2	0.0

[1] Dosage equivalent = actual amount of pesticide applied per hectare per application, relative to recommended per application in the 1993 New England Apple Pest Management Guide.

Table 2. Mean fruit injury (%) caused by apple pests in six second-level IPM test blocks and six first-level IPM control blocks in 1993.[1]

Type of block	TPB[2]	EAS	PC	GFW	AS	AMF	CM	LR	LAW	SJS	FS	SB	Other
Test	7.0a	0.1a	0.3a	0.0a	0.3a	0.7a	0.2a	0.8a	0.4a	0.0a	7.1a	0.2a	0.0a
Control	6.5a	0.1a	0.1a	0.0a	0.0a	0.3a	0.0a	1.0a	0.1a	0.0a	5.1a	0.1a	0.1a

[1] Means in each column followed by the same letter are not significantly different ($p<0.05$, Mann-Whitney U test criterion). All data were taken at harvest. Data from all trees within a block were pooled to give a mean value for the block.

[2] TPB = tarnished plant bug; EAS = European apple sawfly; PC = plum curculio; GFW = green fruitworms; AS = apple scab; AMF = apple maggot fly; CM = codling moth; LR = leafrollers; LAW = lesser appleworm; SJS = San Jose scale; FS = flyspeck; SB = sooty blotch.

plant bug. Most fruit injured by this insect can be marketed without downgrading. The incidence of apple scab was slightly but not significantly greater in test blocks than in control blocks: 0.3% vs. 0.0% (Table 2).

After mid-June, test blocks received no insecticide against fruit-injuring pests, compared with a mean of 1.6 dosage equivalents and 2.2 application events in control blocks (Table 1). Test blocks received one less dosage equivalent of fungicide than control blocks (1.8 vs. 2.8) and 0.7 fewer application events (2.5 vs. 3.2) (Table 1). Combined injury on harvest fruit samples by insects causing damage after mid-June (apple maggot, codling moth, leafrollers, lesser appleworm, San Jose scale) averaged slightly but not significantly greater in test blocks than in control blocks (2.1 vs. 1.4%) (Table 2). Among these pests, apple maggot caused much of the injury in the test blocks (0.7%), with 'Delicious' injured more than 'McIntosh' or 'Cortland'. As shown by capture of apple maggot flies on unbaited red spheres placed at the interior of all blocks, fewer flies penetrated the ring of interception traps in test blocks than penetrated treatments with insecticide in control blocks (7.7 vs. 11.0 flies/trap, respectively; difference not significant). On average, 5,023 apple maggot flies per test block were captured on the interception traps, indicative of an extremely high maggot fly pressure.

Although the difference was not statistically significant, injury from flyspeck was greater in test than in control blocks: 7.1% vs. 5.1% (Table 2). The incidence of sooty blotch averaged 0.2% and 0.1% in test and control blocks, respectively (Table 2). Summer pruning significantly reduced the incidence of flyspeck: 5.3% vs. 7.5%.

The amount of acaricide (principally prebloom oil) applied against spider mites averaged about the same in test blocks as in control blocks (2.4 vs. 2.2 dosage equivalents, 3.3 vs. 3.4 application events) (Table 1). Average populations of spider mites were about the same in test and control blocks, as were average populations of the most abundant species of predatory mites (*A. fallacis* and *Zetzellia mali* [Ewing]) (Table 3).

The average amount of insecticide used against other leaf-feeding arthropods (leafminers, leafhoppers, aphids) was slightly greater in test than in control blocks (0.4 vs. 0.2 dosage equivalents, 0.5 vs. 0.2 application events). Some of this insecticide was directed against leafminer adults before bloom. For the test blocks, we took a particularly conservative approach to leafminer control, recommending prebloom treatment with diflubenzuron rather than summer treatment, even when the need for it was questionable. Summer treatment could have disrupted our ability to evaluate second-level IPM practices against codling moth, lesser appleworm, and leafrollers because diflubenzuron is toxic to these pests. Compared with control blocks, mean populations in test blocks were somewhat lower for leafminers, somewhat greater for rose leafhoppers, and about the same for white apple leafhoppers, woolly apple aphids, and apple and spirea aphids, with none of these differences statistically significant (Table 3). Aphid predators were slightly but not significantly more abundant in the test blocks (Table 3). Parasitoids of second-generation leafminers, the most damaging generation, and predaceous spiders, whose diet may include both leafminer larvae and leafhopper nymphs and adults (Wisniewska et al., 1993), were significantly more abundant in the test blocks (Table 3).

Discussion

Although not all components of second-level apple IPM as put forward here were fully in use in the commercial test blocks in 1993, some tentative conclusions can be drawn about the benefits and shortcomings of those practices that were in use. Our monitoring of fruit-injuring arthropod pests active until mid-June in test and control blocks resulted in no difference in insecticide use and little difference in injury to harvested fruit. From mid-June onward, withholding all insecticides against fruit-injuring arthropods and using biologically based management methods instead of insecticides resulted in slightly but not significantly greater insect injury to fruit compared with control blocks under chemically based first-level IPM. Populations of most foliar pests did not reach damaging levels in any test or control block. Exceptions were European red mites, which reached damaging numbers in three test and three control blocks, and rose leafhop-

Table 3. Mean population levels (% leaves or terminals infested) of foliar arthropod pests and their natural enemies in six second-level IPM test blocks and six first-level IPM control blocks in 1993.[1]

	Foliar pests[2]						Natural enemies[2]				
	ERM				AA		Mite Predators		Aphid	Leafminer	
Type of Block	TSM	LM	WALH	RLH	SA	WAA	*A. fallacis*	*Z. mali*	Predators	Parasitoids	Spiders[3]
Test	22a	8a	4a	8a	29a	8a	4a	10a	17a	55a	1.5a
Control	19a	17a	4a	2a	27a	8a	3a	8a	13a	37b	0.9b

[1] Means in each column followed by the same letter are not significantly different ($p<0.05$, Mann-Whitney U test criterion). On each sampling date, data from all trees within a block were pooled to give a mean value for that date and block. Data from each block for all sampling dates combined for each species activity period were then pooled to give a mean season-long value for that block.

[2] ERM, TSM = European red and two-spotted spider mites; LM = leafminer larvae; WALH = white apple leafhoppers; RLH=rose leafhoppers, AA, SA = apple and spirea aphids; WAA = woolly apple aphids; Aphid predators = *Aphidoletes aphidimyza* and *Syrphus ribicola* combined; Spiders = several families of predaceous spiders.

[3] Mean number per tree in branch-tap samples.

pers, which reached damaging numbers in one test block. It is encouraging that leafminer parasitoids and predaceous spiders were significantly more abundant in the test blocks, but it is disappointing that predatory mites were not more abundant in the test blocks. The fact that acaricide use was not reduced and that mite predators did not build up in the test blocks may have resulted largely from unplanned use of benomyl and mancozeb to control summer diseases during the second part of the season.

The higher disease incidence in test blocks poses a problem, although the difference was not significant. The fact that on average, only 0.5 less total dosage equivalents of fungicide was used in the test blocks also was discouraging. Applications against apple scab were similar in both types of blocks and generally were effective. Growers did not reduce fungicide use markedly during the second part of the season in test blocks, possibly because they perceived inoculum pressure to be high and were unwilling to compromise on fungicide use.

Some components of second-level IPM pose special biological or operational challenges and opportunities to practitioners. For example, brambles such as blackberry and raspberry bushes next to orchards or vineyards support valuable predatory mites (Boller et al., 1988; Tuovinen and Rokx, 1991). Biological control of pest mites could be enhanced by promoting brambles in or near orchards. Also, when brambles are in flower they furnish nectar to parasitoids. Furthermore, brambles are among the weeds that compete least with apple trees for nutrients and water but compete most effectively with other weeds that place stress on apple trees. In principle, therefore, brambles can reduce the need for herbicide. On the other hand, brambles are leading sources of summer disease inoculum and rose leafhoppers. They also pose difficulty to pickers harvesting on-tree or dropped fruit. For these reasons, brambles ought to be eliminated in or near orchards. Second-level IPM calls for orchard entomologists, pathologists, and weed scientists to reconcile these conflicting interests. Our program will give priority to removing brambles to reduce summer-disease inoculum and rose leafhoppers. Another example of how orchard pathologists and entomologists may disagree concerns balancing the benefits of certain fungicides (e.g., benomyl, mancozeb) for control of diseases against their detrimental effects on predatory mites or as phytotoxicants when their use is not carefully timed with respect to acaricide or insecticide application. Similar disagreements may arise between horticulturalists and entomologists regarding postbloom application of carbaryl, which is an effective fruit thinning agent but harms predaceous mites (Croft, 1990). Even the choice of cultivar may generate special pest problems. For example, 'McIntosh' is highly susceptible to apple scab and to excessive preharvest fruit drop, while 'Cortland' is very susceptible to scab and leafroller injury (leafrollers feeding in cavities created by opposing fruit stems can survive pesticide applications), and 'Delicious' is very susceptible to rapid buildup of spider mites. In our program, priorities among these conflicting interests, although not yet fixed, will be determined largely by horticultural and marketing aspects. As mentioned earlier, summer pruning may offer an opportunity for reducing buildup of summer diseases, leafminers, and aphids and for reducing fruit drop, thereby meeting complementary disciplinary interests.

For controlling arthropods, the key to eventual grower adoption of second-level IPM methods as described here lies in minimizing their cost and complexity to make them commensurate with their benefits. For example, three fundamental components of second-level IPM for Massachusetts are: removing unsprayed apple and pear trees within 100 m of the orchard perimeter to prevent immigration of codling moth and lesser appleworm; ringing the perimeter of the orchard with interception traps to control apple maggot flies; and removing drops to discourage within-orchard buildup of all three pests. Preliminary calculations suggest that the cost of just one of these biologically based measures (sticky-coated interception traps against apple maggot, estimated at $190/ha for 1993) substantially exceeds the cost of using chemically based methods against all three pests (estimated at $110/ha for 1993). Moreover, about half the cost of using sticky-coated apple maggot interception traps in 1993 was for qualified labor, which usually is less available than effective pesticides. Even if labor-saving pesticide-treated spheres (Duan and Prokopy, in press) eventually substitute for sticky-coated spheres to control apple maggot flies, the extra organizing effort required to use the new practices successfully might be unacceptable to growers.

For controlling summer diseases, we need to develop a method that will let growers have confidence in stopping the use of fungicides after early July. One approach is optimal timing of late June and early July fungicide treatments and a threshold to signal the need for later treatment. Lacking adequate tools to measure inoculum density and disease pressure, most growers in 1993 assumed that rain showers in August would lead to disease problems, and sprayed accordingly. We are developing methods to predict the best timing for summer-disease fungicides. Such tools should lower the perceived risk and convince growers that they can stop using fungicides in summer unless disease pressure warrants a late-season application. There is evidence that in New England, particularly in the north, summer disease pressure warrants late-season fungicide applications only in some years.

We believe that second-level IPM has merit for Massachusetts apple orchards. Its value at present might be greatest for growers who place high priority on minimizing pesticide applications, either to reduce intrusion on neighbors or the environment near their orchards or to reduce or eliminate pesticide residue on fruit at harvest. Without some refinement of present second-level IPM practices, however, the risk of late season arthropod and disease injury to fruit may be slightly greater under second-level IPM than under non-IPM or first-level IPM. Therefore, we anticipate that growers who sell at roadside stands or other retail outlets might be more inclined to adopt current second-level IPM practices than growers who only sell wholesale for eventual purchase at supermarkets, where perfect-looking fruit is demanded. To appeal to a broad range of commercial growers, some second-level IPM practices must be refined to make them more economical and reliable.

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INSTITUTE NEWS

Wallace Institute Board Elects Four New Members

The Wallace Institute's Board, at its mid-year meeting on September 10 in Madison, WI, elected four new members who will start their terms in March, 1995. On the Friday evening preceding the meeting, the board attended a reception at the University of Wisconsin hosted by the College of Agricultural and Life Sciences, and Cooperative Extension. Following the Saturday meeting, board members toured several research projects at the Michael Fields Agricultural Institute in East Troy, WI, including an integrated cropping systems trial which compares the production, profitability, and environmental impact of six different cropping systems that range from high to low in levels of purchased inputs and crop diversity. The new board members are:

Dr. Frederick Kirschenmann, farmer and manager of Kirschenmann Family Farms, Windsor and Medina, N.D.; former Chair of the North Central Sustainable Agriculture Research and Education (SARE) program's Administrative Council; and current member of the Wallace Institute's President's Council.

Dr. Frederick R. Magdoff, Professor in the Department of Plant and Soil Science, University of Vermont; Chair, Soil Science Society of America's Soil Test and Plant Analysis Committee; and Coordinator of the Northeast Region SARE program.

Dr. Mazo Price, Dean and Director/Professor, School of Agriculture and Home Economics, 1890 Research and Extension Programs, and Professor, Department of Agriculture, University of Arkansas at Pine Bluff; and former project leader, Farming System Research Project, World Bank, Rwanda.

James H. Stephenson, Advisor to the Governor of Pennsylvania; chair, Inter-Agency Council on Food and Nutrition; and former Executive Director, Pennsylvania Coalition on Food and Nutrition.

Members of Wallace Institute's President's Council Named

Michael Heller, President of the Wallace Institute, has announced the members of the 1994-1995 President's Council, formed four years ago to provide guidance and support for Wallace Institute activities in promoting a more sustainable agricultural system in the United States and abroad.

Members are: Dr. Jill Shore Auburn, University of California, Davis; Dr. Charles Benbrook, Benbrook Consulting Services; Norman A. Berg, Washington Representative, Soil and Water Conservation Society; Hon. Bob Bergland, Roseau, MN; Hon. George E. Brown, Jr., U.S. House of Representatives; Ron Ellermeier, farmer, Glenvil, NE; Robert Gray, Resource Management Consultants; Ralph Grossi, President, American Farmland Trust; Dr. R. Jim Hildreth, Elmhurst, IL; Ms. Dana Jackson, Land Stewardship Project; Dr. Dennis R. Keeney, Director, Leopold Center, Iowa State University; Hon. Patrick J. Leahy, U.S. Senate; Dan Martin, Director, World Environment and Resources Program, MacArthur Foundation; Dr. Ned S. Raun, Stillwater, OK; Ronald L. Rosmann, farmer, Harlan, IA; R. Neil Sampson, Executive Vice President, American Forestry Association; Edward Sills, Pleasant Grove Farms, CA; Dr. David G. Topel, Dean, College of Agriculture and Director of Experiment Station, Iowa State University; and Dr. Stephen Viederman, President, Jessie Smith Noyes Foundation.

Kathleen Merrigan Joins Wallace Institute Staff as Senior Analyst

Kathleen Merrigan, a former Senior Legislative Staff Member of the U.S. Senate Committee on Agriculture, Nutrition, and Forestry, has joined the Wallace Institute as Senior Policy Analyst. She will play a dual role, assuming responsibility for coordinating legislative and regulatory affairs for the Institute as well as undertaking important analytical efforts beginning with an intensive critique of sustainability definitions. Ms. Merrigan's work on the Senate Agriculture Committee from 1987 to 1992 included responsibility for science and technology policy development and overseeing agricultural appropriations for Committee Chairman Patrick Leahy. She recently completed courses and comprehensive exams for her Ph.D from the Massachusetts Institute of Technology and is now working on her dissertation on defining sustainability in agriculture.

Mycorrhizae in sustainable agriculture. I. Effects on seed yield and soil aggregation

Gabor J. Bethlenfalvay and José-Miguel Barea

Abstract. *Vesicular-arbuscular mycorrhizal (VAM) fungi colonize plant roots and the surrounding bulk soil. They transport mineral nutrients from the soil to the plant and carbon compounds from the plant to the soil, and have pervasive effects on plant form and function and on the composition of the soil microbiota. This experiment evaluated VAM effects on plants and soil to determine if VAM fungi mediate a relationship between changes in seed yield and soil aggregation. In a pot experiment with peas, an isolate of the VAM fungus* Glomus mosseae *(Nicol. & Gerd.) Gerd. and Trappe did not significantly affect seed yield (8%), but improved soil aggregation by 400% in one soil, a gray silt-loam high in organic matter (OM) and phosphorus. In another soil, a yellow clay-loam low in OM and phosphorus, seed yield was enhanced significantly (57%), but there was only a small change (50%) in aggregation. The results suggest that carbon allocation between the plant (measured as seed yield) and the soil (measured as the formation of water-stable aggregates) is influenced by this VAM fungus. The soil appeared to gain carbon at the expense of carbon lost by the plant. Mycorrhizal fungi thus seem to affect two biologically controlled aspects of sustainable agriculture: plant production and soil quality.*

Key words: pea, plant growth, soil conservation, vesicular-arbuscular mycorrhizal fungi, water-stable soil aggregates

Introduction

The roots of most crop plants and weeds are colonized by beneficial vesicular-arbuscular mycorrhizal (VAM) soil fungi, forming symbiotic associations called mycorrhizae ("fungus roots") (Harley and Smith, 1983). These fungi have a pervasive influence on plant form and function, often making the plant obligately dependent on its endophyte (Smith and Gianinazzi-Pearson, 1988; Graham et al. 1991). Because of their effects on plant growth and development, VAM fungi are considered integral parts of their host plant (Gianinazzi et al., 1982). It therefore is not surprising that until recently, research on VAM fungi focussed only on their effects on plants, either individual plants under controlled conditions (Reid, 1990) or plant communities both in natural (Barea and Jeffries, in press) and disturbed (Bagyaraj, 1992) ecosystems. This interest in the plant was enhanced by economic considerations, specifically the potential of VAM fungi to improve plant nutrition and yield (Bethlenfalvay, 1992), to protect plants from pathogens (Linderman, 1992), and to improve plant resistance to environmental stress (Sylvia and Williams, 1992).

These goals of conventional, production-oriented agriculture (Cooke, 1982) continue to be valid, but there are now additional priorities. These priorities stem from the realization that the production base — a healthy soil that can support high-yielding plants — is a fragile resource in limited supply that must be protected and conserved to sustain agricultural production (Reganold et al., 1990). Mycorrhizal fungi, as colonizers not only of roots and the rhizosphere but also of the bulk soil, appear to play as great a role in conserving soil as in enhancing plant productivity. They mediate the movement of mineral nutrients from the soil to the plant and of carbon compounds from the plant to the soil. Although this exchange is known to benefit plants, only recently have its effects on soil aggregation been recognized (Tisdall and Oades, 1979) and fully appreciated (Tisdall, 1991; Miller and Jastrow, 1992). However, a relationship between VAM effects on plants and soil has not been demonstrated. The purposes of this experiment were to determine both host-plant and host-soil responses to a VAM fungus in a controlled and therefore simplified model setting, and to evaluate the VAM effect on the plant-soil system in the context of sustainable agriculture's simultaneous goals of plant production and soil conservation.

Materials and Methods

Experimental design

Soil type and VAM colonization were used as factors in a randomized 2×2 factorial design involving 2 soils, with the plants

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in each soil grown with or without VAM fungi. The experimental unit was one pot containing one plant, with each of the 4 treatments replicated 5 times. (This design was part of a larger experiment to be discussed in later reports.) The data were evaluated by analysis of variance, and significant main effects were further evaluated by student's t-test. Actual significance levels are presented (except that levels below 0.001 are reported simply as "p<0.001") instead of using an arbitrary 5% significance level, because this allows a more precise interpretation of each result's statistical significance (Nelson, 1989).

Biological materials and soil types

Pea (*Pisum sativum* L., cv.'Lincoln') plants were inoculated with an isolate of the VAM fungus *Glomus mosseae* (Nicol. & Gerd.) Gerd. and Trappe. This isolate was originally obtained from Barbara Mosse (Rothamsted Experimental Station, Hertfordshire, England), and cultured at the Estación Experimental del Zaidín (EEZ) for over 10 years on *Sorghum halepense* L. in EEZ soil. A saturating amount of inoculum was used, consisting of at least 1000 spores and sporocarps and 500 heavily colonized root fragments per pot.

The soils were obtained from the garden of the EEZ at Granada (Soil G) and from near Guadalupe, Extremadura (Soil E), Spain. Soil G, a gray silt-loam (43% sand, 48% silt, 9% clay) had a pH of 7.6, and organic matter (OM) and N contents of 11.4 and 2.8 g/kg, respectively. Other nutrients (in mg/kg) were: P ($NaHCO_3$-extractable), 43.1; Cu, 12; Fe, 18; Mn, 37; and Zn, 12. Soil E, a yellow clay-loam (42% sand, 40% silt, 18% clay) had a pH of 7.0, OM and N contents of 3.2 and 2.0 g/kg, respectively. Other nutrients (in mg/kg) were: P ($NaHCO_3$-extractable), 20.6; Cu, <1; Fe, 23; Mn, 53; and Zn, 2. The soils were autoclaved for 1 hour on 3 consecutive days. Sievings (30 µm) of the inoculum free of VAM propagules were added to all soils to equalize the microbiota.

Growth conditions

Plants were grown as greenhouse pot cultures from January to March 1993 in Granada, Spain. Temperatures were controlled to vary between 15 and 32°C, but because of occasional power failures the maximum day/night range was 41°C to 4°C. The pots were wrapped in reflective aluminum foil to shield the soil from the sun. They contained 350 g of soil mixed with 350 g of sand. The sand was sieved to a particle-size range of 2 to 3 mm. The VAM inoculum was mixed uniformly with the growth medium before planting. Pea seeds were pregerminated and selected for uniformity. Seedlings were thinned from 3 to 1 plants per pot after 1 week of growth. The plants were watered with a 4 mM solution of $Ca(NO_3)_2$ twice a week initially, then daily during the last 3 weeks of the experiment. They were harvested after 8 weeks of growth, when the pods were mature.

Assays

Roots were washed and fresh mass was determined. Samples were weighed and stained for VAM colonization (Phillips and Hayman, 1970). The length of the root sample was determined by counting the total (+VAM and -VAM) intersections (gridline intersect method, Ambler and Young, 1977). Total root length was estimated from the ratio of the sample to total fresh mass. Colonized root length was calculated according to Giovanetti and Mosse (1980). Seeds were weighed after drying at 70°C for 2 days.

The growth medium was permitted to dry before harvest so that it could be easily crumbled and shaken loose from the roots. It was then air-dried and crushed with a dough roller. In this process, soil aggregates smaller than 2 mm were protected by the presence of the large (>2 mm) particles of sand. The crushed sand-soil mixture was sieved (2 mm openings) to separate and discard the coarse (>2 mm) sand. The remaining (dry, <2 mm) soil fraction was sieved again (1 mm openings) to separate it into 2 size classes (>1 mm and <1 mm). The soils of these two size classes were weighed and the large aggregates (>1 mm) that at this stage still contained fine (<2 mm) sand were reported as a percentage of total soil.

Water-stable soil aggregates (WSA) were determined according to Kemper and Rosenau (1986) with modifications. Dry aggregates (>1 mm) were spread in a thin, even layer (30 g) on a 1 mm sieve stacked above a 0.5 mm sieve of the same diameter (10 cm). The sieves were submerged rapidly into water (taking care first to eliminate air bubbles from below the 0.5 mm mesh) and agitated through a 10-cm water column with even, vertical strokes at 16 strokes per minute for 3 minutes. The WSA remaining on the sieves were washed onto preweighed filter paper with a wash bottle, dried at 110°C, and weighed. Next, the sand content of the WSA (size intervals 1 to 2 mm and 0.5 to 1 mm) was determined as follows. The sample was placed back on its sieves, submerged in a dilute NaCl solution, and washed to disperse the aggregated soil. The sand remaining on the sieves was dried, weighed, and subtracted from the original WSA to get the mass of sand-free aggregated soil.

The change in aggregation during the experiment was used as a second measure of the effect of VAM on WSA. The WSA status of the pre-experiment soil was determined (10 samples) by the same method as the post-experiment soils at harvest. The percentage difference between the two values was calculated as $[(WSA_{post} - WSA_{pre})/WSA_{pre}]\times 100$. Positive numbers show aggregation, negative numbers show slaking of the soil during the experiment.

Results

Seed yield of -VAM plants in the two soils depended on soil P content: in low-P Soil E, seed dry mass was lower ($p<0.001$) than in Soil G (Table 1). Colonization by the VAM fungus improved seed development by 57% ($p<.001$) in Soil E plants, but had little effect (8%, $p=0.120$) in plants grown in Soil G. In the +VAM plants, the endophyte apparently equalized seed development: there was no difference in yield between plants growing in E or G soils ($p=0.452$)

Root length behaved like seed yield (Table 1), showing no VAM effect in Soil G

Table 1. Seed yield, root development, and soil aggregation status of potted pea plants.[1]

Observations	Soil G			Soil E		
	+VAM	-VAM	p-value	+VAM	-VAM	p-value
Seed dry mass (g)	2.2	2.0	0.120	2.3	1.3	<0.001
Soil aggregates						
Dry aggregates	30.1	26.7	0.008	45.2	38.8	0.031
WSA <1 mm	6.9	5.4	0.043	5.8	4.4	0.028
WSA >1 mm	13.0	2.6	<0.001	22.3	11.3	0.003
WSA Ratio	1.9	0.5	<0.001	3.9	2.6	0.029
Root parameters						
Fresh mass (g)	5.4	4.5	0.001	4.7	3.2	<0.001
Length (m)	25.8	24.7	0.434	21.9	17.0	0.019
Colonized length (m)	4.7			13.9		

[1] Plants were grown in a silt-loam (G) or loam (E) soil and were colonized by the vesicular-arbuscular mycorrhizal fungus *Glomus mosseae* (+VAM) or left uncolonized (-VAM). Dry aggregates were greater than 1 mm. Water-stable soil aggregates (WSA) were in two size classes: 1 to 2 mm and 0.5 to 1 mm. p-value refers to the statistical significance of the difference between +VAM and -VAM means by a t-test.

(p=0.434) but a marked increase (p=0.019) in +VAM over -VAM plants in Soil E. In contrast to seed yield, root lengths of the +VAM plants in the two soils were different (p=0.043). Only 18% of the root length in Soil G was colonized by the VAM fungus, compared with 63% in Soil E. Fresh root mass of +VAM and -VAM plants differed (p<0.001) within each soil type (Table 1). However, the difference in fresh root mass between the two soil types dependend on VAM treatment (Soil G vs. Soil E: +VAM, p=0.058; -VAM, p<0.001).

The dry aggregation status of the soil can be interpreted as a measure of physical cohesion among soil particles and soil and fine sand. This cohesion was greater in Soil E than in Soil G in both the +VAM (p<0.001) and the -VAM (p=0.004) treatments (Table 1). Within soil type, dry aggregation was greater for the +VAM than the -VAM treatment (Soil E, p=0.008; Soil G, p=0.031).

The percentage of large (>1 mm) WSA for both +VAM and -VAM treatments was markedly greater (p<0.01 for both) in Soil E than in Soil G, perhaps because of the higher (two-fold) clay content of the former, or because of the greater length of colonized roots (Table 1). Differences in large WSA between +VAM and -VAM treatments also were large (Soil G, p<0.001; Soil E, p=0.003). Unlike with the large WSA, the percentages of small WSA (Table 1) were similar between the two soil types within both VAM treatments (E vs. G: +VAM, p=0.101; -VAM, p=0.077). However, there were marked differences between the +VAM and -VAM treatments within the same soil type (Soil G, p=0.043; Soil E, p=0.028). Thus, the differences in small WSA between the +VAM and -VAM treatments were less than the differences in large WSA. This may be ascribed to an accelerated slaking of the large WSA in the -VAM treatments. That is, large WSA in the -VAM treatments were converted to small ones at a faster rate than in +VAM treatments. This process is reflected in the large/small WSA ratio (Table 1), which is a measure of the relative changes in WSA size.

The change in WSA status during the experiment was positive for the small WSA (Fig. 1). In Soil G, the increase was small (p=0.324) in the -VAM treatment, but large (p<0.001) in the +VAM treatment, as it was for both the +VAM and -VAM treatments in Soil E (p<0.001). The increase in small WSA was greater in Soil E than in Soil G in the soils of both the +VAM (p=0.014) and the -VAM (p=0.002) treatments. For the large WSA, however, there was a marked difference not only in the magnitude but also in the direction of change: in the +VAM treatments WSA were formed, while in the -VAM treatments the soil disaggregated. The apparent increase in small WSA in the -VAM treatment probably resulted from the slaking of the larger aggregates: as macroaggregates disintegrate, the proportion of microaggregates increases (see Cambardella and Elliott, 1993). The severe slaking of the large -VAM aggregates was probably enhanced by the large day-night temperature differences and the concomitant shrinking/swelling of the soils. This process apparently was ameliorated in the +VAM treatments.

Discussion

We have used an artificial agrosystem (see Bethlenfalvay and Schüepp, 1994), simplified to contain only its most basic components (plant and sterile soil), to show some effects of a member of an ever-present but little-known class of soil organisms on both plant and soil. These organisms, the VAM fungi, are best known as plant symbionts, and have been shown to alter fundamentally the development, nutrition and physiology of plants (see Bethlenfalvay, 1992). Much less is known, however, of their role in soil development, even though their hyphae are known to transport mineral nutrients from

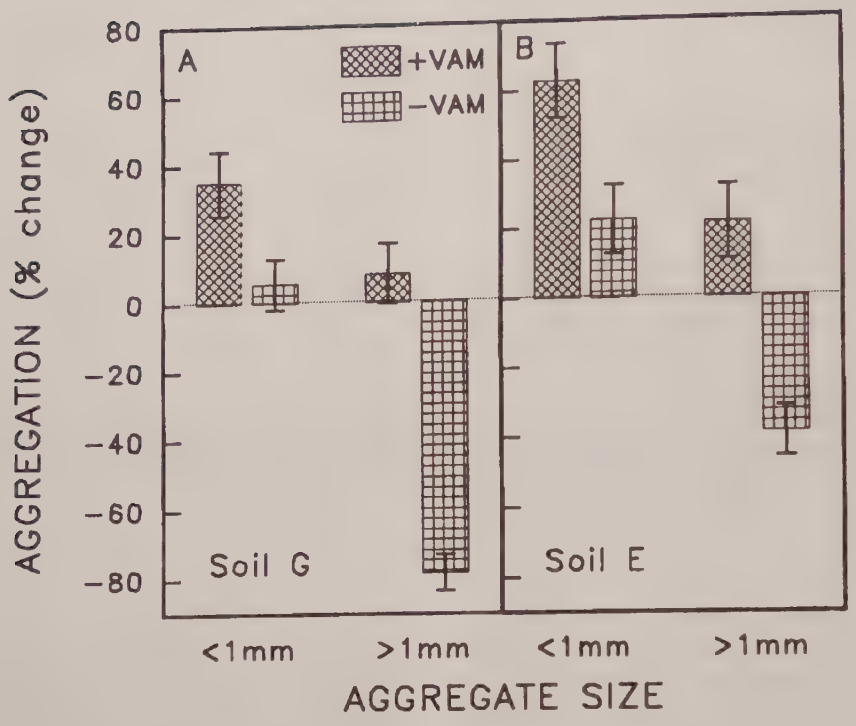

Figure 1. Percent change in water-stable soil aggregates (WSA) during the experiment. Soils were inoculated with a vesicular-arbuscular mycorrhizal fungus (+VAM) or not inoculated (-VAM). The sizes of WSA were 1 to 2 mm or 0.5 to 1 mm. Values reflect the means and standard errors of 5 replicates.

the soil to the plant and carbon compounds from the plant to feed the soil biota.

Our results, which focus on combined VAM effects on both plant and soil, reveal three salient points: 1) root colonization by VAM fungi affects soil aggregate status; 2) the VAM condition of the plant-soil system affects the relationship between plant and soil development; and 3) the concept of "mycorrhizal effectiveness" needs to be reevaluated. Defined in the past by VAM-mediated changes in host-plant growth (see Graham et al., 1991), VAM effectiveness in the context of sustainability must include VAM effects on the host soil. Simultaneous VAM-mediated enhancement of both plant and soil development is possible only when the production of carbohydrates is not limited by some external factor. When the supply of carbon is limiting, allocation priorities that probably are regulated at the symbiosis level (Andersen and Rygiewicz, 1991) will direct its flow to the strongest sinks within the plant-fungus association (Wang et al., 1989; Eissenstat et al., 1993) or to the ultimate sink, the soil (Jakobsen and Rosendahl, 1990). If "soil quality is the key to sustainable agriculture" (Papendick and Parr, 1992), the role of soil as a sink for carbon becomes a useful one, even if it is at the expense of plant growth.

The data illustrate these considerations. In Soil G, there was no VAM effect in the conventional sense: the difference between the seed yields of +VAM and -VAM plants was small (8%, p=0.120; Table 1). However, the difference between the percentage of large WSA in the +VAM and -VAM treatments was large (400%, Table 1), and the -VAM soil disaggregated, whereas WSA increased in +VAM soil relative to the original soil (Fig. 1). Since root length was the same in the +VAM and -VAM treatments (Table 1) and the soils were not root-bound, the aggregation effect cannot be ascribed to compaction through root pressure in a confined volume, but rather to the activity of the VAM mycelium (Thomas et al., 1993). This raises two questions: 1) whether the improved WSA status of the +VAM soil (carbon gained by the soil, Jakobsen and Rosendahl, 1990) was at the expense of carbon that could have contributed to seed development (carbon lost by the plant); and 2) how improved WSA status may benefit the development of subsequent crops. The level of colonization, although low, was sufficient (by our experience) to enhance plant growth.

In Soil E, there was a respectable 56% increase in seed yield of +VAM plants over the -VAM control, but the improvement in large WSA was only 50%. Why was carbon allocation between plant and soil controlled differently in Soil E (favoring plant over soil) compared with Soil G? There are several possible reasons: physiological changes (Koide and Schreiner, 1992) resulting from more intense colonization (63% vs. 18%); differences in soil texture (more clay, less organic matter) or mineral nutrients (less P, Cu, and Zn); or differences in the intensity of hyphal permeation of the soils. The experiment was not designed to answer these questions, but to point them out because of their relevance to alternative agricultural practices (Parr et al., 1992).

Summary and Conclusions

In one soil, root and soil colonization by a VAM fungus did not enhance seed yield, but markedly improved aggregation compared with the -VAM control. In another soil, the same VAM fungus improved soil aggregation only slightly but enhanced seed yield significantly. Thus, the VAM fungus affected the development of both its plant and soil hosts. The flux of carbon to the soil and its availability to the soil biota apparently were enhanced by the VAM soil mycelium, which accounts for the VAM effect on soil aggregation. Of interest are the conditions that stimulate the plant to allocate carbon preferentially to its

own development or to its fungal endophyte and ultimately to formation of soil structure. Also of interest is the role that the VAM fungus may play in influencing the carbon allocation process. Its ability to affect the balance of plant or soil development shows that it has the potential of a biological tool for use in both plant production and soil conservation.

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Reduced chemical input cropping systems in the southeastern United States. II. Effects of moderate rates of N fertilizer and herbicides, tillage, and delayed cover crop plow-down on crop yields

Larry D. King

Abstract. *In a previous study of reduced chemical cropping systems (N from legumes; chisel plow and disk tillage; cultivation for weed control) in the southeastern U.S., corn and wheat yields were less than half those obtained with recommended practices. The following practices were studied as possible ways to improve yields in the reduced chemical systems: 1) conventional tillage (chisel plowing and disking), inorganic N at 70 or 140 kg/ha, and either cultivation or herbicides; 2) early versus late plow-down of clover green manures; 3) supplemental inorganic N fertilizer on corn and wheat in rotations relying on clover green manures for N; and 4) nicosulfuron herbicide banded on corn.*

Yield of soybean in the rotations was not affected by any of these practices. With herbicides and fertilizer N at 140 kg/ha, continuous corn yields with no-till and conventional tillage were equal in 1990 and 1992, but no-till yield was 30% higher in 1991. When cultivation was used for weed control in the conventional tillage treatment, corn yield was similar to that of no-till with herbicide in the one year when rain was plentiful (yield 6000 kg/ha) . However, in 2 of 4 dry years, yields (<2600 kg/ha) were higher with no-till. Clover biomass consistently increased by between 700 and 3500 kg/ha when plow-down was delayed from mid-April to early or mid-May (13 to 26 days). However, biomass N content increased significantly (by between 35 and 90 kg/ha) in only 2 of 5 years. Corn yields were affected in only 2 of 12 possible comparisons. In these cases, delayed clover plow-down reduced yield by about 50%. Supplementing corn with 45 kg N/ha and banding nicosulfuron increased yields, but only to between 62 and 84% of yields with recommended practices. Supplementing wheat with 45 kg N/ha increased yields by half, but only to between 40 and 60% of the yields with 90 kg N/ha.

Key words: reduced chemical systems, banded herbicide, green manure, corn, wheat, soybean, clover, no-till, conventional tillage, N fertilizer

Introduction

Concerns about the economic and environmental performance of cropping systems managed with synthetic fertilizers and pesticides have led to several studies of cropping systems that do not receive these inputs. In Nebraska, recommended rates of fertilizer and herbicides were compared with manure and no herbicides in a rotation of corn (*Zea mays)*/soybean (*Glycine max*)/corn/oat (*Avena sativa)*-sweet clover (*Melilotus officinalis)* (Andrews et al., 1990). Over a 12-year period, combined yield of corn, soybean, and oat receiving manure and no herbicides was 95% of the yield with fertilizer and herbicides. In Pennsylvania, a conventionally managed corn/soybean rotation was compared with a corn/soybean/small grains-red clover (*Trifolium pratense)* rotation managed with reduced chemical inputs (Liebhardt et al., 1989; Andrews et al., 1990). Soybean yield was not affected by management system. Generally, corn grain yield with conventional management was superior to yield with low-input management for the first 4 years, but for the next 3 years yields in the two systems were similar.

A long-term experiment was initiated in 1985 in the Piedmont of North Carolina to determine the agronomic feasibility of substituting legumes and mechanical weed control for fertilizer N and pesticides in cropping systems commonly used in the southeastern U.S. (King and Buchanan, 1993). In that experiment, four cropping sequences were established:

1. Continuous corn;
2. 2-year rotation: corn/wheat (*Triticum aestivum*)-soybean;
3. 4(3)-year rotation: corn/wheat-soybean/corn/red clover hay; (after the first cycle, changed to a 3-year rotation: wheat-soybean/corn/red clover hay);
4. Continuous grain sorghum (*Sorghum bicolor*).

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Two management systems were used:

- *Current Management Practices* (CMP) = no-till planting and recommended rates of herbicides, insecticides, and fertilizer;
- *Reduced Chemical Inputs* (RCI) = conventional tillage; N supplied either by a winter green manure crop of crimson clover (*Trifolium incarnatum*) or by the residual N from red clover managed for hay; cultivation for weed control; no insecticides.

Over a 7-year period, soybean yields generally were similar in the two systems. However, yields of corn and wheat receiving RCI management were less than half those with CMP management. Low yields were due mainly to weed competition and insufficient N, so an obvious next step was to supplement the RCI systems with N and herbicides. Hargrove (1986) and Touchton et al. (1982) found that grain sorghum grown after crimson clover did not respond to fertilizer N applications, but Ebelhar et al. (1984) found that corn following crimson clover did respond. In controlling morning-glory (*Ipomoea hederacea*) and sicklepod (*Cassia obtusifolia*) in soybean, Poston et al. (1992) found that two cultivations resulted in yields as high as those obtained with combinations of herbicide and cultivation, but profit was slightly higher with one cultivation plus banded herbicides. Buhler et al. (1992) found that cultivation for weed control in soybean was as effective as using herbicides under low weed pressure, but cultivation plus banded herbicides was superior under high weed pressure.

Anderson (1990) conducted a study in North Carolina of conventional farmers and farmers who minimized the use of chemical inputs (alternative farmers). She found that 23% of the alternative farmers used some commercial synthetic fertilizers and 67% used spot application of herbicides.

Supplemental fertilizer and herbicides can improve yields, and many alternative farmers use these practices. Therefore, in 1990 we added treatments with supplemental N and banded herbicides to the original experiment (King and Buchanan, 1993) to determine if yields obtained with RCI management could be increased. This report discusses the results of those treatments and several others not previously reported.

Methods

The methods, described in detail by King and Buchanan (1993), can be summarized as follows. Combinations of the four cropping sequences and two management systems were established in September 1985 on a Cecil soil (Typic Kanhapludults, clayey, kaolinitic, thermic). A randomized complete block design with four replicates was used, with plots of 8×30 m. The experiment was designed with extra plots and extra replicates of some RCI treatments so that new treatments could be added as the experiment progressed. Data were analyzed by analysis of variance. Means were separated by least significant differences calculated at the 10% level of probability (Ray, 1982).

Continuous corn receiving synthetic N

Four treatments were compared in which corn was grown continuously with synthetic fertilizer N (Table 1). During the planning stage, an organic farmer suggested we include treatments receiving fertilizer but no pesticides, so treatments R1b and R1d were added: fertilizer N (as NH_4NO_3) was applied after chisel plowing and disking, and cultivation for weed control. In 1990, treatment C1d-ct was added. It was the same as the previously reported treatment C1d except that chisel plowing and disking were used for corn rather than no-till. Another treatment had been included to determine the response of corn to carbofuran (Furadan) insecticide placed with the seed at planting. This treatment was included because of corn rootworm (*Diabrotica undecimpunctata howardi*) in previous studies at this site. However, no response to carbofuran was found, so this treatment is not included in this discussion.

Supplemental N and banded herbicides

In the previously reported treatments R1, R2, and R4 (Table 2), weed control was not adequate and insufficient N was supplied by legume green manures. Therefore, R1N, R2N, and R4N were added in 1990 (Table 2). For corn, fertilizer N was banded over the row at planting and nicosulfuron (Accent) herbicide was banded over the row at first or second cultivation to control johnsongrass (*Sorghum halapense*). Wheat received N fertilizer at 45 kg/ha in February. Soybean received no herbicide in 1990, but in 1991 and 1992 sethoxydim (Poast) was banded over the row at first or second cultivation to control johnsongrass.

Green manure management

As previously reported (King and Buchanan, 1993), in the RCI treatments corn planting was delayed two weeks beyond the CMP planting date to allow additional accumulation of clover biomass and N. However, corn yield normally declines as planting date is delayed (Anderson and Wagger, undated). Therefore, in the added treatments R1e, R2e, and R4e, crimson and

Table 1. Continuous corn treatments receiving synthetic N fertilizer

Code[1]	Tillage	Weed control	Fertilizer N rate (kg/ha)	Treatment duration
C1d	none	herbicides[2]	140	1986-92
C1d-ct	chisel plow/disk	herbicides	140	1990-92
R1b	chisel plow/disk	cultivation	70	1986-90
R1d	chisel plow/disk	cultivation	140	1986-90

[1] Underlined treatments were not reported in King and Buchanan (1993).
[2] Alachlor, glyphosate, atrazine, linuron, and nicosulfuron (see King and Buchanan, 1993)

Table 2. Treatments involving supplemental N, banded herbicides, and alternative green manure management.[1]

Code[2]	1985-86		1986-87		1987-88		1988-89		1989-90		1990-91		1991-92		Fert. N (kg/ha)	
	winter	sum.	winter	sum.	winter	sum.	winter	sum.	winter	sum.	winter	sum.	winter	sum.	Corn	Wheat
Current Management Practices (CMP)[3]																
2-yr rotation																
C2d	(wheat)	bean		corn	(wheat)	bean		corn	(wheat)	bean		corn	(wheat)	bean	105	90
Reduced Chemical Inputs (RCI)[4]																
Continuous corn																
R1	(CriCl)	corn	(CriCl)	corn	(CriCl)	corn	(CriCl)	corn	(CriCl)	corn	(CriCl)	corn	(CriCl)	corn	0	—
R1N	"		"		"		"		N at planting, banded herbicide →						45	—
R1e	"		"		Clover killed & corn planted about 2 weeks earlier than in R1 →										0	—
R1Ne	"		"		"		"		N at planting, banded herbicide →						45	—
2-yr rotation																
R2	(wheat)	bean	(CriCl)	corn	(wheat)	bean	(CriCl)	corn	(wheat)	bean	(CriCl)	corn	(wheat)	bean	0	0
R2N	"		"		"		"		N on wheat & corn, banded herbicide on corn						45	45
R2e	"		"		"		Clover killed & corn planted about 2 weeks earlier than in R2								0	0
4-yr rotation									*3-yr rotation*							
R4	(wheat)	bean	(CriCl)	corn	(RedCl)	RedCl	(RedCl)	corn	(wheat)	bean	(CriCl)	corn	(RedCl)	RedCl	0	0
R4N	"		"		"		"		N on wheat & corn, banded herbicide on corn						45	45
R4e	"		"		"		Clover killed & corn planted about 2 weeks earlier than in R4								0	0
R4r	same as R4e except red clover in 1989 and crimson clover in 1991 removed as hay.														0	0

[1] ( ) indicates winter crop. CriCl = crimson clover; bean = soybean; RedCl= red clover.
[2] Underlined treatments were not reported in King and Buchanan (1993).
[3] Herbicides used each year; soil insecticide used for corn 1986-1990 (see King and Buchanan, 1993).
[4] Herbicide used on wheat in fall of 1991 and banded on all corn and bean treatments in 1992; no insecticides in any treatments.

red clover were incorporated and corn was planted on the same date as in the CMP treatments (Table 2). One other RCI treatment (R1Ne) was added to combine early planting with N banded at planting and nicosulfuron herbicide banded during cultivation. In the added treatment R4r in the RCI 4(3)-year rotation, crimson or red clover was removed as hay to determine if the biomass was more valuable as a green manure or as hay.

Prolific hybrids

Additional treatments were included from 1987 through 1989 in which a prolific (multi-ear) corn hybrid was grown continuously with N supplied by crimson clover (RCI) or fertilizer (CMP). This hybrid was included because it has been reported to have greater N use efficiency (ratio of grain weight to N supply) than that of nonprolific hybrids (Moll et al., 1987). We thought that under RCI management, this hybrid might perform better than the nonprolific hybrid used in the other treatments. However, yield differences between the prolific and non-prolific hybrids were not significant, so these treatments are not included in this discussion.

Results

Continuous corn receiving synthetic N

The effects of herbicides, N rates, and tillage on continuous corn are shown in Fig. 1. When rainfall was low (1986-1988, 1990, see King and Buchanan, 1993), yields of continuous corn with conventional tillage and cultivation (R1b and R1d) were comparable for 70 and 140 kg N/ha. The 140 kg/ha rate was superior only in 1989, when rainfall was plentiful. At this N rate, no-till plus herbicides (C1d) was superior to conventional tillage with cultivation for weed control (R1d) in 1987 and 1988. No-till was superior to conventional tillage with herbicide in 1991 only (C1d vs. C1d-ct).

Green manure management

Delaying the date of killing crimson and red clover before planting corn significantly increased aboveground biomass of the clover in most cases (Fig. 2). However, the amount of N contained in the biomass was increased only in 1988 and 1992. Apparently, clover accumulates a substantial amount of structural carbohydrates during the 2- to 3-week period between early and late bloom stages, but N fixation is constant or declining. For example, in 1989 the average C/N ratio of the crimson and red clovers increased from 16 to 23 during the period 19 April to 15 May. Wagger (1989a) reported a 40% increase in crimson clover biomass and a 10% increase in

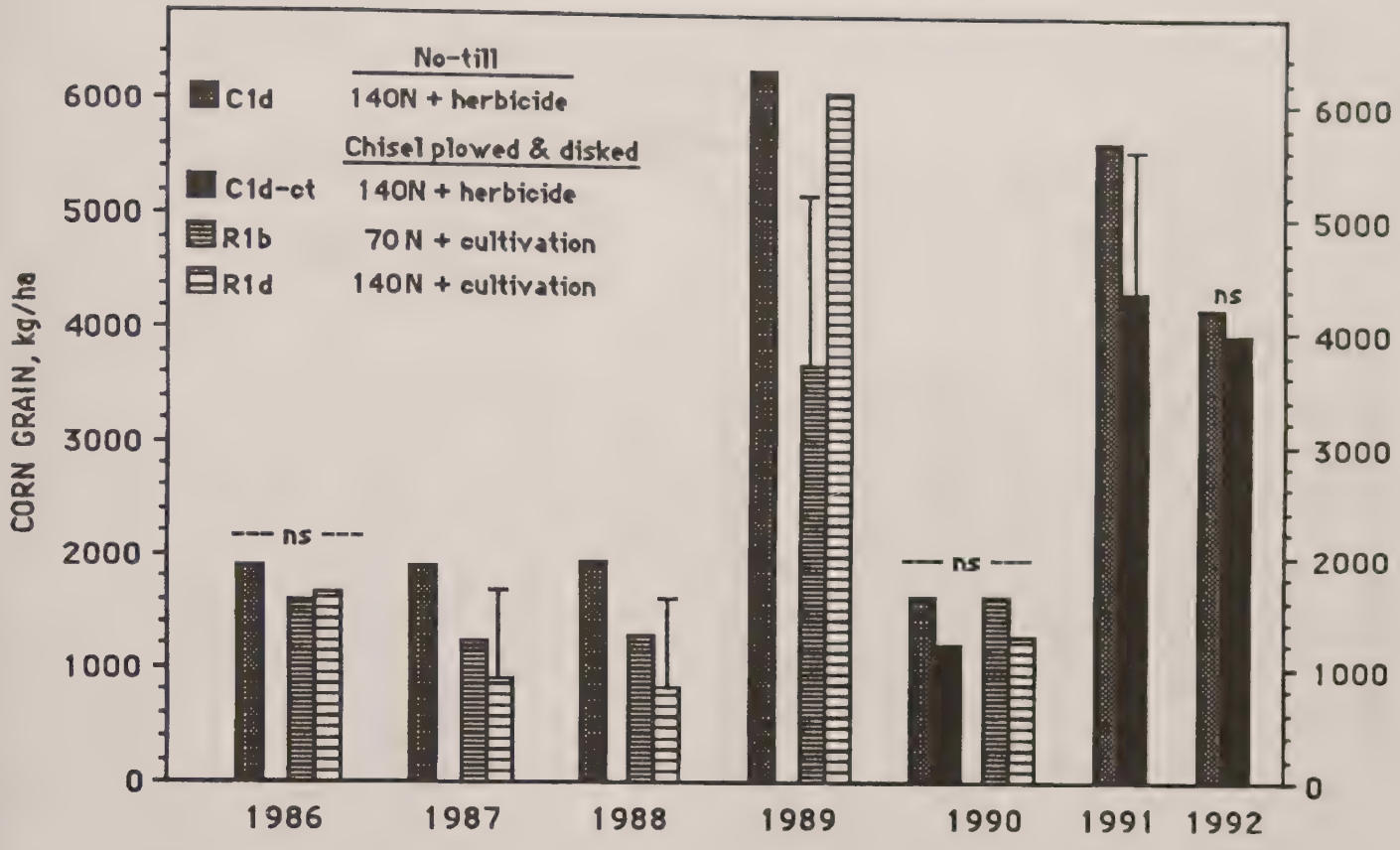

Figure 1. Effect of pesticides, N fertilizer, and tillage on grain yield of continuous corn. In all figures, within a given year the vertical bar is the least significant difference at the 10% level of probability; "ns" indicates difference is not significant.

N accumulation over a 2-week period in late April.

Corn yield was not affected strongly by planting date (Fig. 3). In 1989, planting date was not significant within a given cropping system, but a date × cropping system interaction was significant; yield with late planting in the 2-year rotation was significantly higher than yield with early planting in the continuous corn treatment. In 1990, early planting was superior to late planting when fertilizer N and banded herbicide were applied, but was not superior in their absence. In contrast, in 1992, early planting was superior when N fertilizer and herbicide were not used. In a two-year study in the Piedmont of North Carolina with no-till corn after crimson clover, Wagger (1989b) found no significant effect of early vs. late date of killing clover and planting corn.

Early planting is recommended so that pollination is completed before the hot and dry periods occurring during late June and early July in North Carolina (Anderson and Wagger, undated). To determine if soil moisture at anthesis was related to grain yield, available soil moisture was estimated by the procedure of van Bavel and Verlinden (1956). The procedure uses rainfall, potential evapotranspiration, and soil moisture storage capacity to estimate available moisture. Soil moisture conditions were similar during anthesis of early and late planted corn in 1988, 1989, and 1991 (Fig. 4), when yields were not affected by planting date (Fig. 3). However, in 1990 and 1992, when moisture was more favorable during anthesis of the late planted corn, yields were higher with early planting (Fig. 3). Apparently, factors other than moisture at anthesis affected yield more in those years.

Removing red clover as hay in 1989 and crimson clover as hay in 1991 did not significantly affect subsequent corn yields (Table 3). Johnsongrass competition was heavy in both years (King and Buchanan, 1993) and the low corn yields did not allow a good evaluation of the effect of removing or plowing the clovers. Removal significantly lowered N concentration in the ear leaf at anthesis in 1989 (17.5 vs. 20.4 g/kg) but not in 1991 (17.5 vs. 19.0). Similarly, in a 3-year study in the Piedmont of Georgia in which grain sorghum was no-till planted into crimson clover, Touchton et al. (1982) found that removing the crimson clover had little or no effect on yield. In the Coastal Plain of North Carolina, Hubbard (1986) noted that corn yield dropped from 7300 to 4300 kg/ha when hairy vetch (*Vicia villosa*) was removed rather than plowed down. In Florida, Gallaher (1993) found that yield of irrigated corn, which ranged from 4500 to 9380 kg/ha, was not reduced when vetch, crimson clover, or lupine (*Lupinus angustifolius* L.) was removed rather than plowed down. How-

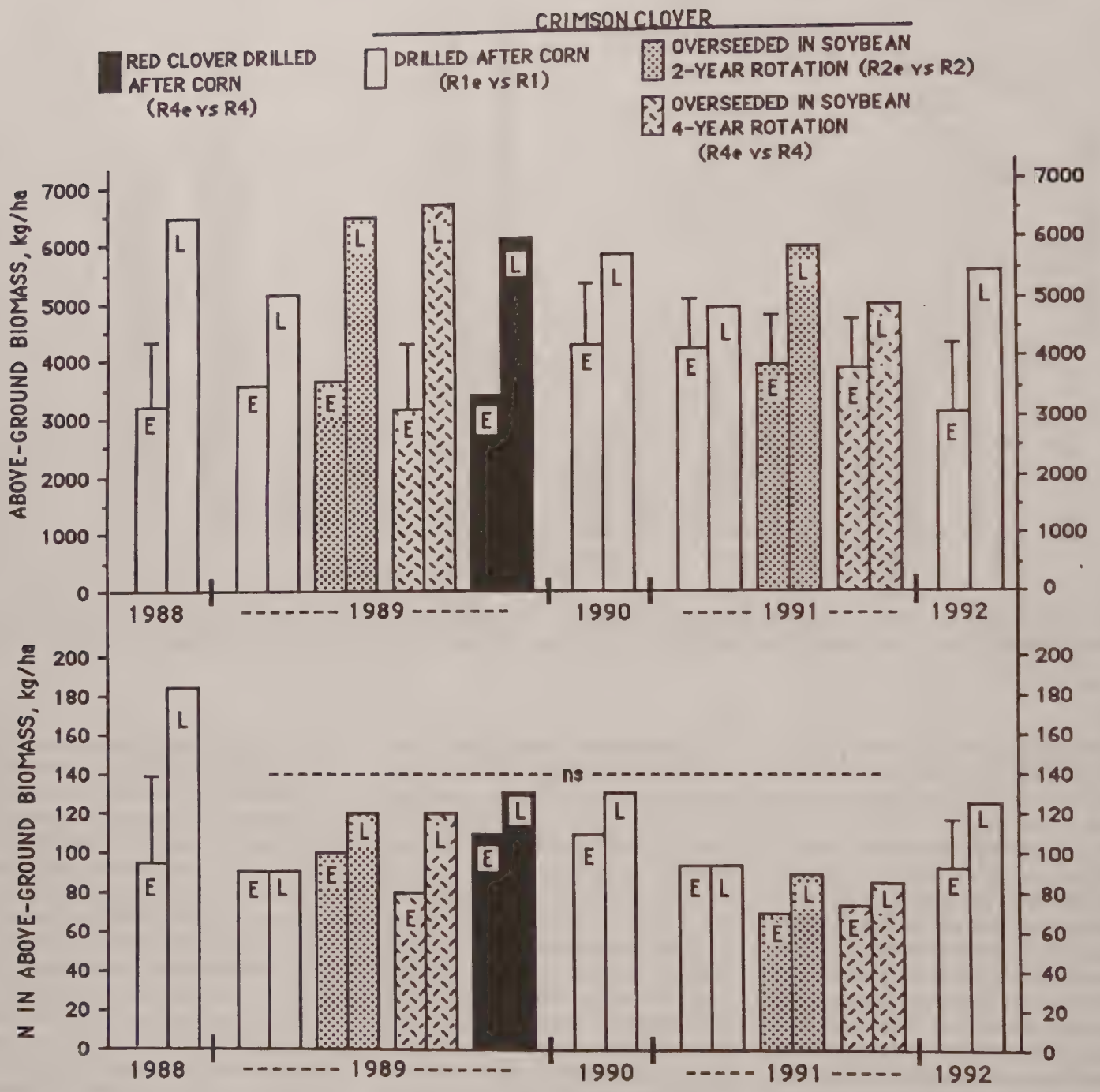

Figure 2. Effect of date of killing crimson and red clover (E = early bloom, L = late bloom) on biomass and N accumulation (1988: 11 vs. 25 April; 1989: 19 April vs. 15 May; 1990: 9 vs. 23 April; 1991: 17 vs. 30 April; 1992: 15 vs. 30 April). Biomass and N include contribution from winter weeds (see King and Buchanan, 1993).

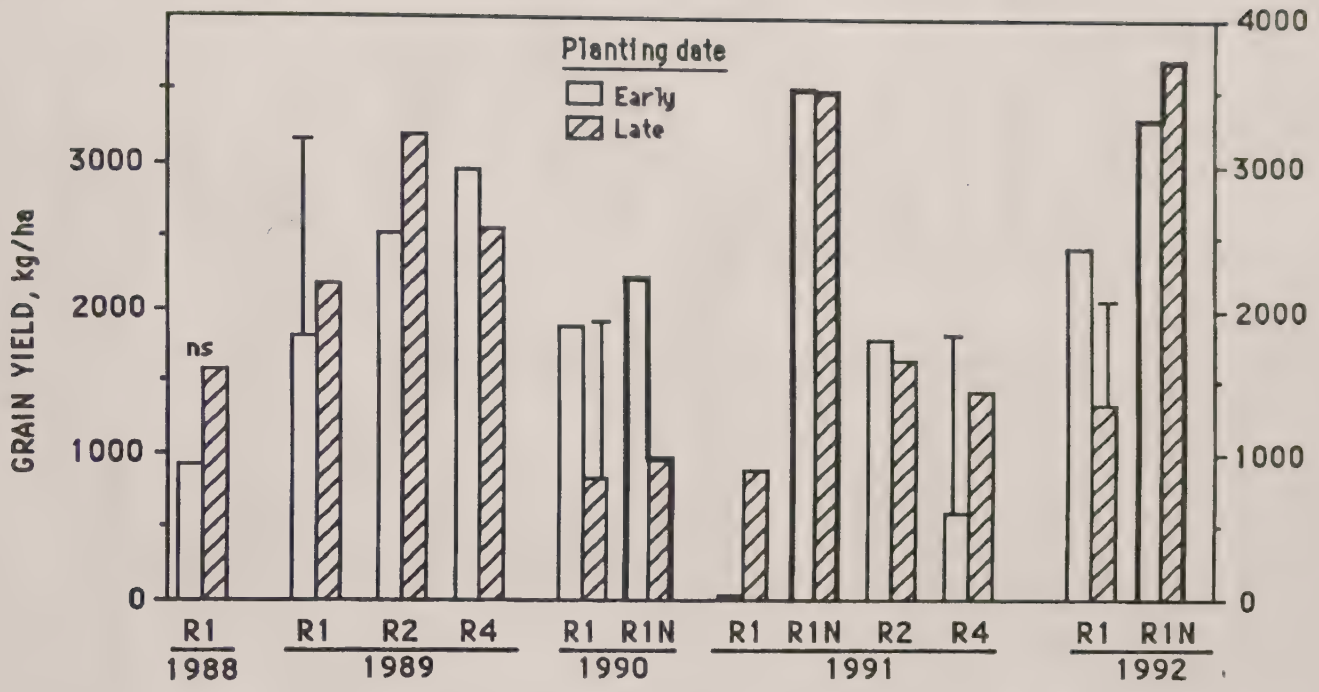

Figure 3. Effect of planting date and fertilizer N on corn yield in the reduced chemical input treatments.

Table 3. Legume biomass, legume N content, and corn yield (kg/ha) with and without removal of clover before planting corn.

	1989 Red clover	1991 Crimson clover
Legume biomass	3390	3820
N in legume	104	75
Corn yield		
plowed (R4e)	2400[1]	1450[1]
removed (R4r)	2420	1360

[1] Yield differences between plowed and removed were not significant ($p > .10$) in either year.

ever, N concentration in the ear leaf generally was lower when the legume was removed.

Delaying clover plow-down should increase N accumulation but decrease N availability because of the increase in C/N ratio. Thus, late plow-down might increase the amount of available N left in the soil after corn harvest. Evidence of this greater residual N was noted in 1990, when wheat following corn had a higher yield in the 4(3)-year rotation when clover had been plowed late rather than early (Fig. 5). This difference was not noted in the 2-year rotation in 1990 or 1992.

Supplemental N and banded herbicides

Application of fertilizer N at 45 kg/ha and herbicide did not increase yield of continuous corn in 1990 (a dry year), but significantly increased it at both planting dates in 1991 and 1992 (Fig. 3, R1N vs. R1). However, yields still were much lower with RCI than with CMP (C1d: 5600 kg/ha in 1991, 4200 in 1992). In the previously cited study by Wagger (1989b), yield of no-till corn after crimson clover increased 12% in response to 100 kg N/ha in a year with adequate soil moisture, but did not respond in a dry year. In Alabama, Oyer and Touchton (1990) applied several rates of N to no-till corn after crimson clover. The maximum response was found at 67 kg N/ha in three instances and at 134 kg N/ha in another. The average increase was 78%. In Georgia, McVay et al. (1989) found little response to N when no-till corn or grain sorghum followed legume cover crops.

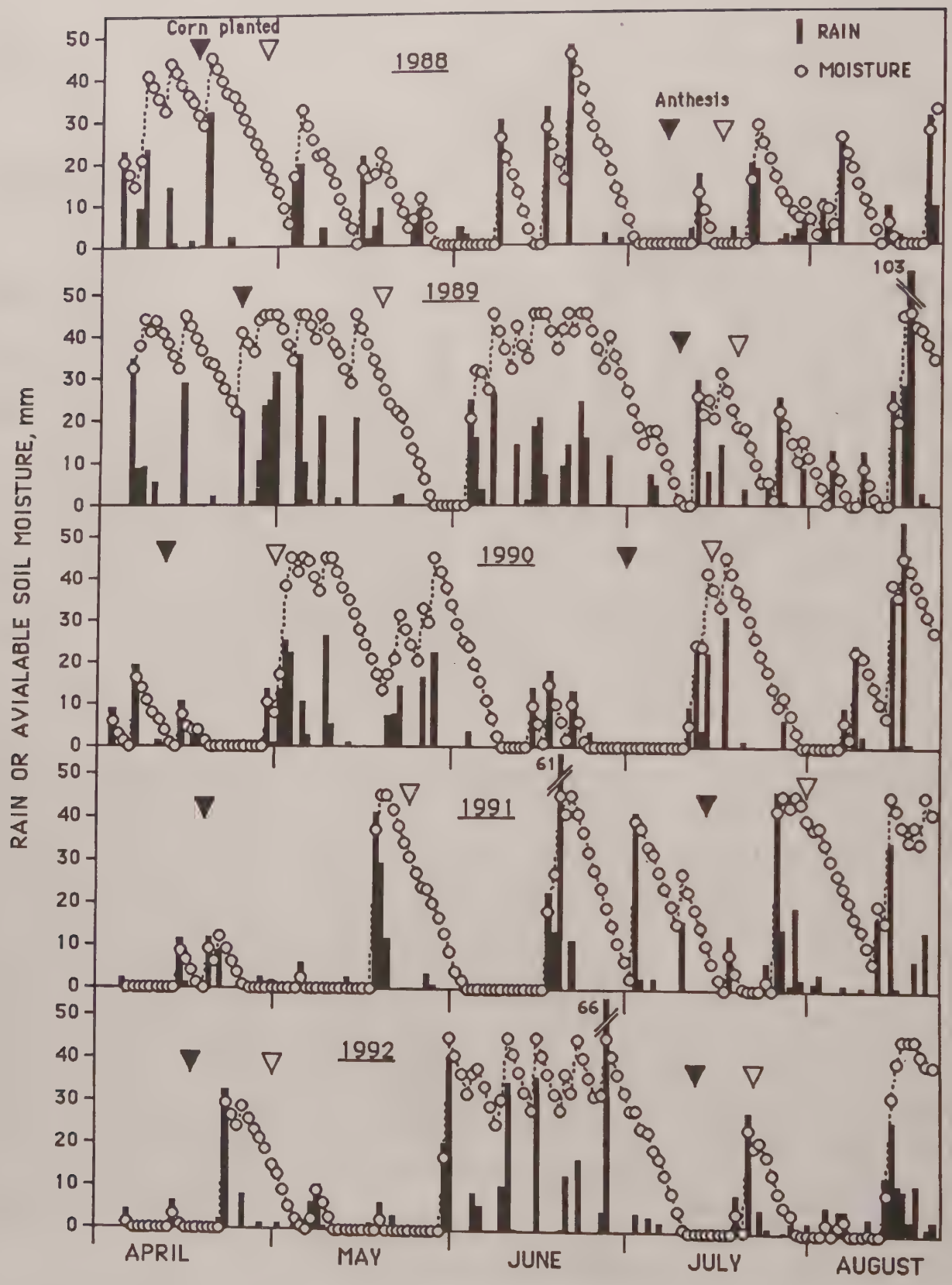

Figure 4. Rain and estimated available soil moisture in the upper 30 cm of soil.

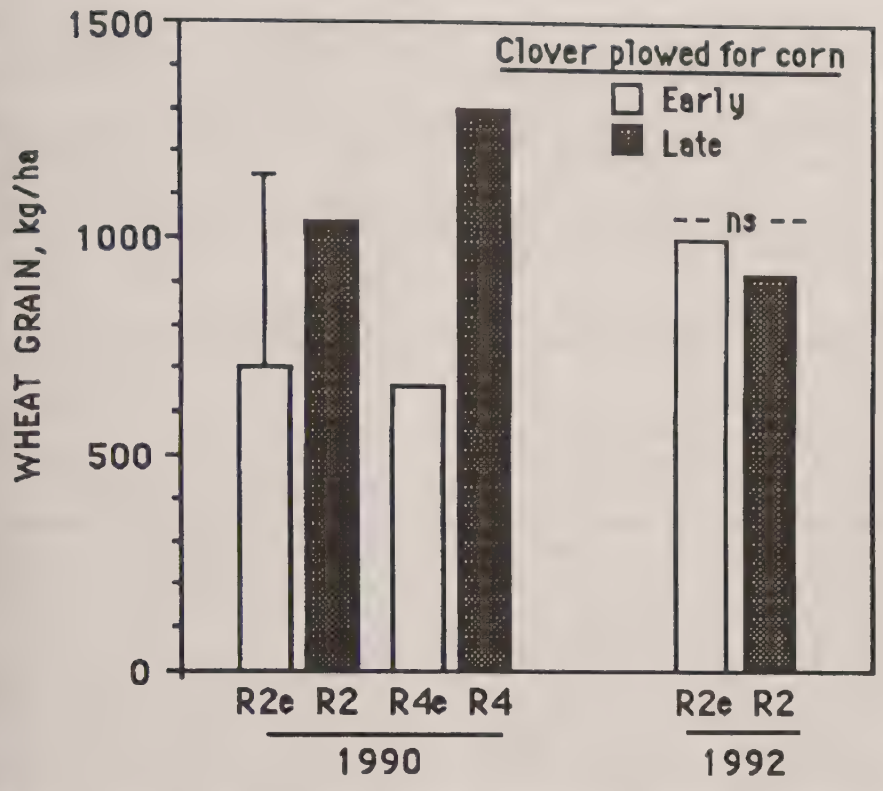

Figure 5. Effect of time of plowing crimson clover before planting corn on yield of subsequent wheat crop.

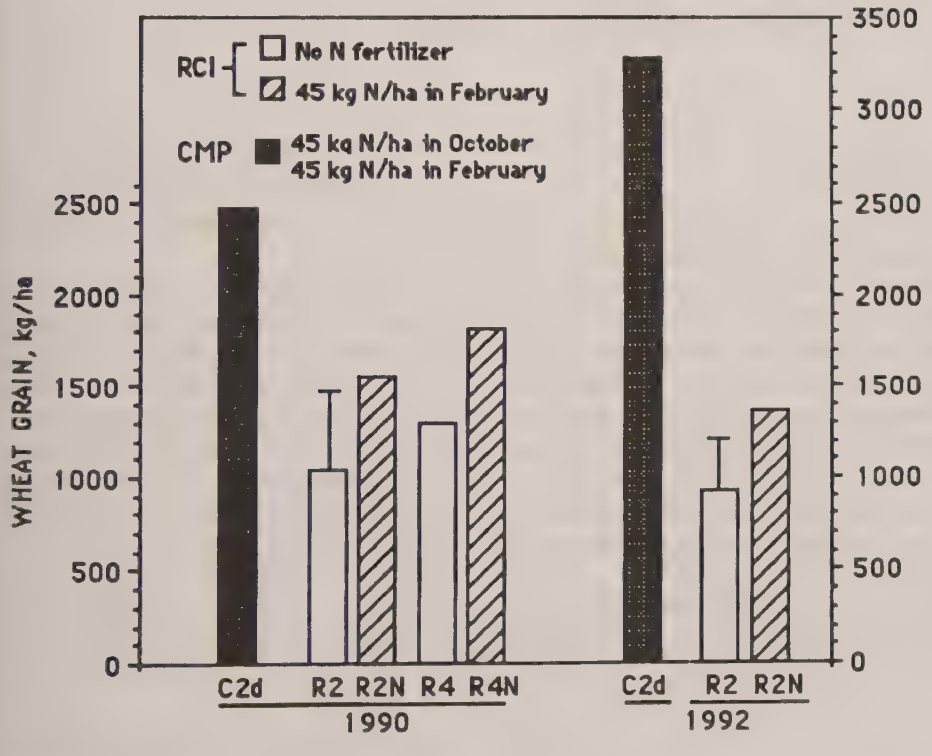

Figure 6. Comparison of wheat yield with CMP vs. RCI with and without supplemental N.

The combination of banding nicosulfuron and cultivation was effective in reducing johnsongrass competition. In RCI continuous corn in 1992, a count of johnsongrass seed heads at harvest showed 50,000/ha with cultivation alone (R1) and 15,000 with nicosulfuron and cultivation (R1N). The count with CMP was 5,000/ha (C1d).

Wheat and soybean yields

Adding half the recommended N rate to RCI wheat increased yields compared with no N, but not to the levels attained with the full N rate in the CMP treatment (Fig. 6). The poor performance of wheat after corn in the RCI systems is what prompted the change from the 4-year to a 3-year rotation in which red clover preceded wheat (Table 2). Generally, soybean yield was not affected by differences in corn and wheat treatments (N, herbicide and date of plow-down) in the 2- and 4(3)-year rotations, so the data are not presented.

Conclusions

- Controlling weeds with herbicides rather than with primary tillage and cultivation resulted in higher yields of continuous corn in 3 of 5 years.
- With supplemental N, banded herbicide, and cultivation, corn yields were higher than with legume N and cultivation, but still were only 60 to 80% of those obtained with recommended rates of fertilizer N and broadcast herbicides. Supplemental N on RCI wheat resulted in yields 40 to 60% of those obtained with the recommended rate of N.
- Delaying clover plow-down to increase clover biomass and N did not increase the yield of subsequent corn crops.
- Prolificacy, soil insecticide, corn planting date (generally) and hay removal did not affect corn yield.
- Soybean yield was not affected by the corn and wheat treatments.

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Farm Profiles Invited

For its new department on alternative agriculture profiles, the *AJAA* welcomes short articles describing farmers who have adopted interesting alternative practices. The articles should include five elements: a brief description of the farm; the problems that made the farmer look for an alternative approach and the reasons why the alternative seemed plausible; a summary of the basic principles behind the alternative (possibly in a sidebar if it interrupts the flow of text); a discussion of how well the alternative has worked; and a discussion of the applicability of the alternative for other farms. The length should be 1500 to 2000 words.

Submissions must be accompanied by a release, signed by the farmer, giving permission for this material to be published in the *American Journal of Alternative Agriculture*. Vol. 3, No. 4, of the *AJAA* has a further description of the department (page 188); or query the editor for further information. Send submissions to the Editor, *AJAA*, 9200 Edmonston Road, Suite 117, Greenbelt, MD 20770-1551.

Letters To The Editor Invited

The *AJAA* welcomes letters, short or long, commenting on articles in this journal or sharing ideas likely to be of interest to other *AJAA* readers. Since our space is limited, we do reserve the right not to publish all letters or, at times, to publish only excerpts from them. To take part in this exchange of ideas, write to: Editor, *AJAA*, 9200 Edmonston Road, Suite 117, Greenbelt, MD 20770-1551.

Grain yield response of corn, soybean, and oat grown in a strip intercropping system

Mohammadreza Ghaffarzadeh, Fernando García Préchac, and Richard M. Cruse

Abstract. *Conventional Midwestern U.S. row crop agriculture has created significant environmental problems and made the farm economy reliant on government subsidies. Environmentally friendly and economically profitable alternatives are badly needed. This study addresses production characteristics of strip intercropping, a system that may meet both requirements. Two experiments were conducted in 1989 and 1990: one on a cooperating farmer's field with ridge tillage and the second at a university research farm with conventional tillage. The objective was to evaluate grain yields of different rows in adjoining strips (3.8 or 4.6 m wide) of three crops. Corn, soybean, and oat strips were either interseeded with nondormant alfalfa or seeded with hairy vetch as a cover crop after oat grain harvest. Outside corn rows had significantly higher yields than center rows in 1990, when plant water stress was low, but under dry conditions in 1989, early season competition for water caused corn to yield less in the row bordering oat than in the row bordering soybean. Comparative soybean yields in border and center rows also depended on rainfall; with adequate water, soybean yield next to the oat strip was greater than or equal to yield in the center of the strip. Oat border rows yielded higher than those in the oat strip center. Timing differences in crop life cycles and water availability seem to influence how these crop species interact, particularly at the border positions. Overall, the strip intercropping system seems a suitable alternative to current practices.*

Key words: cropping systems, rainfall, plant water stress

Introduction

For economic and environmental reasons, alternatives to conventional row crop systems are needed in the midwestern U.S. In Iowa, for example, approximately 17 out of 24 million harvested acres are managed with an annual rotation of corn (*Zea mays* L.) and soybean (*Glycine max* [L.] Merr.). However, designing alternative systems that are both environmentally friendly and economically sound is challenging and will require innovation and creativity.

Designing sustainable cropping systems must consider the characteristics of the crop species as well as economic, social, and environmental factors. For example, proper selection of crops within a system can improve economic return by reducing pest and allelopathic problems observed in monocultures (Cook et al., 1978; Musick and Beasley, 1978; Francis and Clegg, 1990). Pesticide applications may be reduced, favoring the environment. Legumes introduced into a system can fix nitrogen, thus reducing requirements for nitrogen fertilization (Voss and Shrader, 1984; Francis and Clegg, 1990). Diversity within a cropping system can also favor sustainability (Francis and Clegg, 1990). Diversity over time, exemplified by crop rotations, typically increases crop yields compared with monocultures (Crookston et al., 1991). Spatial diversity, exemplified by strip intercropping, potentially will increase total crop production, as shown for strip intercropping corn and grain legumes (Whigham, 1985; Whigham and Bharati, 1985; Francis et al., 1986). Combining diversity in time and space may be the most feasible approach for developing an economically sound and environmentally friendly system.

Crop interactions at strip edges may present a unique opportunity to influence production with strip intercropping. For example, corn border rows consistently yield more than the field average in a corn-soybean strip intercropping system (Francis et al., 1986). The effects of row position on soybean yield are less clear. Because sunlight and available soil water are limited, soybean border rows next to corn strips generally yield less than monocrop soybean (Francis et al., 1986; West and Griffith, 1992). However, Radke and Hagstrom (1976) found that double rows of corn increased soybean yield at distances of two to seven rows from the corn compared with the yield of monocrop soybean fields. It is generally agreed that with corn-soybean strip intercropping, soybean yield averaged across all rows is lower than with monocropping (Francis et al., 1986).

Because they have similar planting times and crop maturity dates, adjacent corn and soybean strips compete throughout their life cycle, as has been documented in the literature discussed previously. Planting an adjacent strip of a crop that

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grows at a different time seems advantageous for avoiding competition. Small grain crops, such as spring wheat (*Triticum aestivum* L.), barley (*Hordeum vulgare* L.), and oat (*Avena sativa* L.), could serve this purpose. Normally they are planted two to three weeks earlier and mature two to three months earlier than corn or soybean. This suggests that favorable border yield responses in corn and soybean may occur.

The objective of this research was to evaluate corn/soybean/oat-legume strip intercropping, and determine grain yield of crops, row by row, within each strip. We hypothesized that including a third crop strip (small grain) in the corn-soybean strip configuration would have three results: 1) higher soybean yield at the oat border than the corn border position; 2) higher small grain yield in strips because of early seeding of small grains, which would lead to little competition at the edge with bordering crops; and 3) higher corn yields in both corn strip border rows than in strip center rows.

Materials and Methods

We conducted experiments at two Iowa locations using a three-crop strip system (Fig. 1). The rotation was corn-soybean-oat, with a forage legume cover crop included in the oat strips. In Experiment I, a mixture of oat and hairy vetch (*Vicia villosa* Roth) was planted after oat grain harvest. In Experiment II, we underseeded nondormant alfalfa (*Medicago sativa* L.) with oat at spring planting. The purpose of the legumes (hairy vetch and alfalfa) is to fix nitrogen and contribute part of that fixed N to the following corn crop. Table 1 shows selected management practices for both sites. We collected data on all three crops in 1989 and 1990 at both sites.

Experiment I was established as part of a commercial farming operation on the Thomas Frantzen farm in Chickasaw County (Northeast Iowa). Strip intercropping was started in 1989, using ridge tillage. Soil types were Cresco (fine, loamy, mixed, mesic Typic Argiudoll) and Floyd (fine, loamy, mixed, mesic Aquic Hapludoll) silt loam.

Crop strip characteristics are shown in Fig. 1. N fertilization for corn (Table 1) was based on the late spring nitrate test (Blackmer et al., 1989). No P or K was applied because of high soil test levels (data not shown). Crops were harvested using a plot combine. Corn and soybean were harvested row by row, taking 30 m per row. Oat grain was harvested with a 1-m wide (5 row) grain platform, taking an area 1 m × 29 m along each edge of the strip and in the center (Fig. 1). All harvested areas were 30 m from the field ends to avoid field edge effects.

Experiment II was established in 1988 at the McNay Research Center in southern Iowa on a Haig (fine, montmorillonitic, mesic Typic Argiaquoll) loam. The site was managed with conventional tillage (fall moldboard plowing and two secondary tillage operations in the spring). Plots were 14 m long by 3.8 m wide, and harvested areas were 10 m long. In this experiment, 5-row equipment was used to maximize wheel track control. Also, N was point injected in the corn and oat strips. Harvest procedures were similar to those

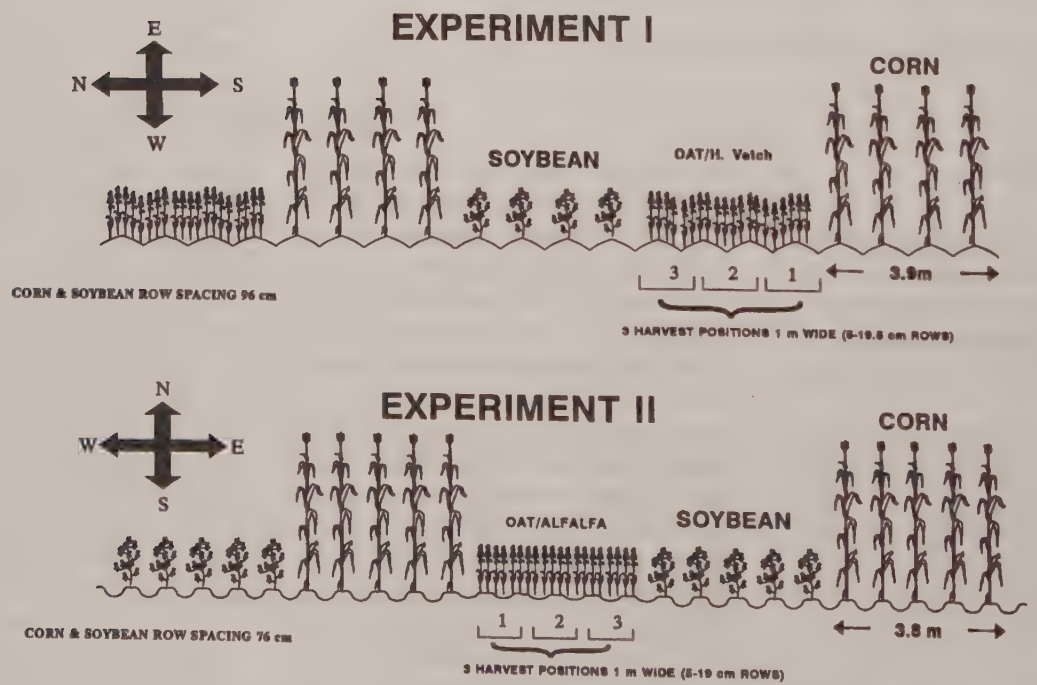


Figure 1. Schematic diagram of strip intercropping for two experiments, including strip direction, orientation, row spacing and small grain harvesting positions.

Table 1. Selected management practices used for each crop in Experiments I and II.

Crop	Row Spacing (cm)	Planting Date 1989	Planting Date 1990	N Rate (kg/ha) 1989	N Rate (kg/ha) 1990	No. of Cultivations 1989	No. of Cultivations 1990	Weed Control Herbicide	Weed Control Method
				Experiment I					
Corn	96	4/29	5/04	10	67	2	2	2,4-D[1] Alachlor[2]	Broadcast Band
Soybean	96	5/10	5/12	0	0	2	2	Alachlor	Band
Oat/HV[5]	19.5	4/06	3/29	0	0	0	0	2,4-D	Broadcast
				Experiment II					
Corn	76	5/10	6/04	67	67	2	1	Alachlor Cyanazine[3]	Band Band
Soybean	76	5/10	6/04	0	0	2	1	Alachlor	Band
Oat/Alf[6]	19	4/03	4/06	0	40	0	0	Glyphosate[4]	Broadcast

[1] (2,4-dichlorophenoxy) acetic acid.
[2] (2-chloro-2:6'-diethyl-N-methoxymethyl) acetanilide.
[3] 2-[4-chloro-6-(ethylamino)-5-triazin-2-yl]-2-methylpropionitrile.
[4] N-(phosphonomethyl) glycine. Applied to overwintered alfalfa before corn planting.
[5] Hairy vetch and oat planted as a cover crop after oat grain harvest.
[6] Oat underseeded with alfalfa in spring.

described for Experiment I. Strip characteristics are shown in Fig. 1. In 1990, the oat yield distribution in strips was evaluated for individual rows in both experiments. Before mechanical harvesting, 3 m of each oat row was harvested by hand.

Both experiments had four replicates. Each block (replicate) included a complete set of three crop strips (corn, soybean, and oat) and one border strip at either side (Fig. 1). Orientation of the strips was fixed. We analyzed each crop separately, with row position within the strip (that is, its position in relation to the other two crops) the "treatment" variable. This differs from the customary replicated single-treatment design in that the "treatment" could not be assigned a random position within the block. We used analysis of variance and orthogonal contrasts to compare the mean yields of individual row positions for a given crop, using a least significant difference (LSD) test at the 5% probability level.

Results and Discussion

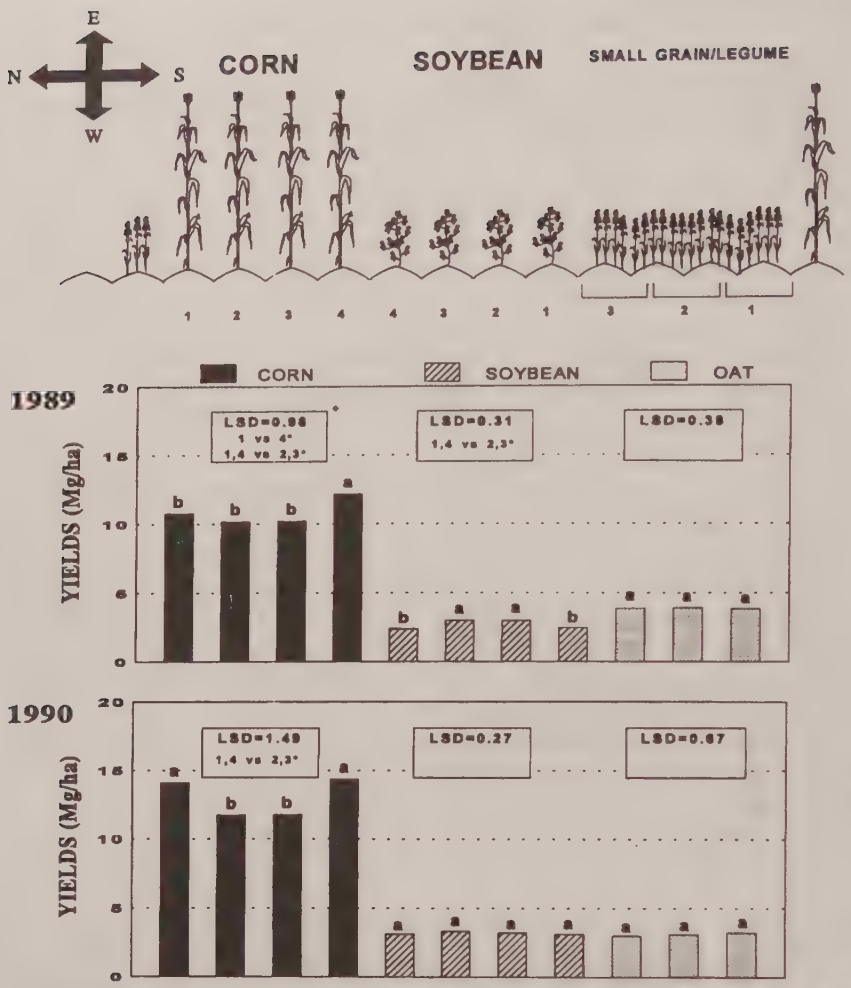
Total precipitation during June, July, and August was below normal in 1989 at both locations. Above-normal rainfall in May at the location of Experiment II resulted in late planting of corn and soybean (Table 1 and 2).

In 1989 in both experiments, corn yield was significantly greater in the row bordering the soybean strip than in the other border row and the strip center rows. In 1990, the row bordering soybean had significantly greater yield than the center rows (Figs. 2 and 3). The corn row bordering the oat strip had significantly higher yield than the strip center rows in 1990. However, at both locations in 1989, the early seeded oat appeared to use water from the corn strip edge, which increased the water stress on corn. This resulted in competition for soil water during June and the first half of July,

Table 2. Monthly precipitation (mm) at both locations from April through August in 1989 and 1990.

Month	Experiment I 1989	Experiment I 1990	Experiment I Normal[1]	Experiment II 1989	Experiment II 1990	Experiment II Normal[2]
April	104	102	76	20	82	89
May	87	89	97	147	161	97
June	76	152	110	75	155	119
July	62	204	112	70	198	94
August	51	178	100	120	91	98

[1] New Hampton, Iowa, 16 km from experiment location (U.S. Dept. of Commerce, 1990).
[2] Chariton, Iowa (U.S. Dept. of Commerce, 1990).



Grain yield with the same letter did not differ significantly within each strip (LSD 0.05)

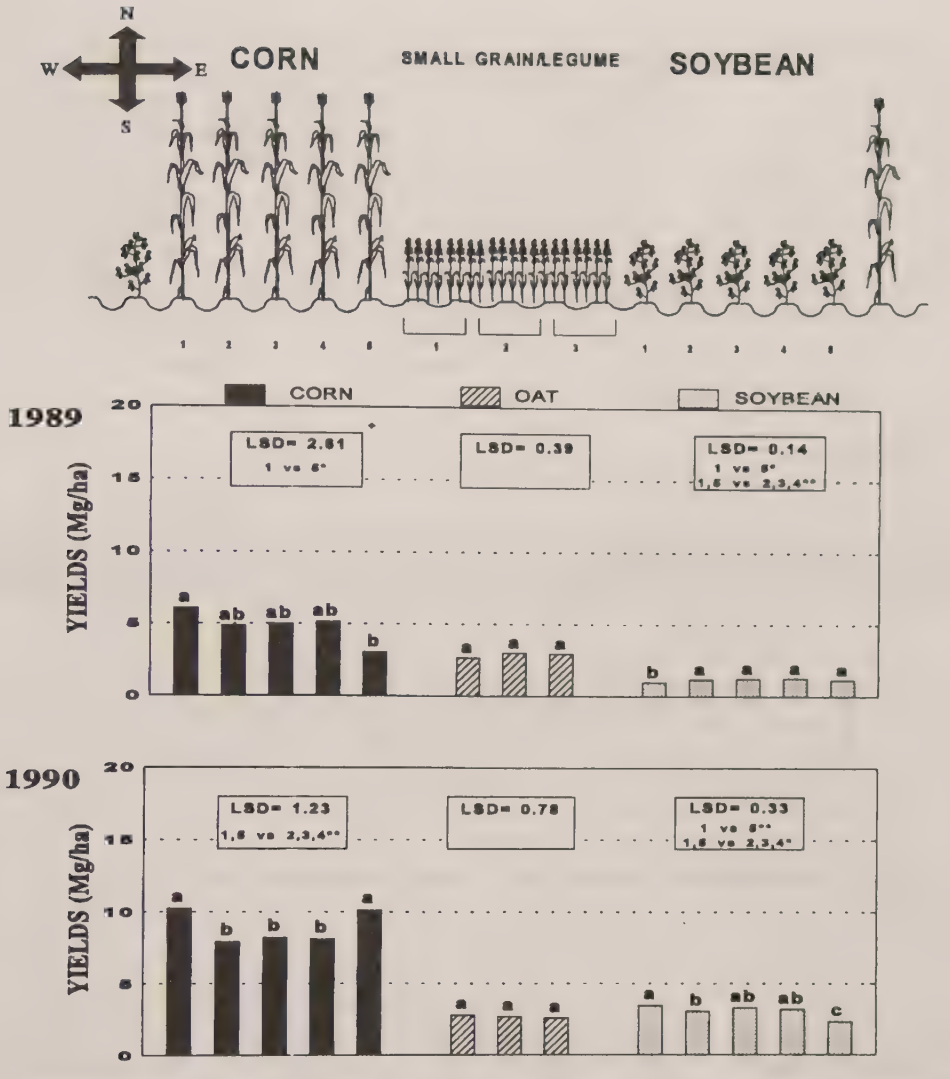
+, *, ** Least significant difference (LSD) and significant contrasts for each crop. Significant at the 0.05 and 0.01 level of probability. Tested contrast: In corn and soybean strips 1 vs 4; 1,4 vs 2,3; 2 vs 3; and in oat strips 1 vs 3; 1,3 vs 2.

Figure 2. Corn, soybean, and oat yield (Mg/ha) as affected by row position within each strip, for Experiment I.

which significantly lowered the yield of corn in the row bordering oat compared with the row bordering soybean. In contrast to 1989, both locations had above normal rainfall in 1990 (Table 2). This resulted in significantly higher corn yield in border positions than in strip centers in both experiments (Figs. 2 and 3).

Yield of soybean in border rows generally was lower than in center rows in 1989. An exception occurred in Experiment II, where soybean yields were very low because of general water stress. The row bordering corn was similar to the strip center rows. In 1990, soybean yield was unaffected by row position in Experiment I, but the row bordering the corn strip yielded significantly less than the other rows in Experiment II. Competition with corn for sunlight probably contributed to the latter result (Francis et al., 1986; West and Griffith, 1992).

At both sites, oat yield was generally higher at the border compared with the center position, although the differences were small and significant only at the 10% level. The three compared positions were each 1 m wide, which included 5 oat rows. The 1-m border positions each included 2 or 3 rows of oat growing in controlled wheel traffic locations. Soil compaction undoubtedly limited the potential for higher yields in these positions, which negatively affected yield in the strip borders. In 1990, row-by-row hand harvested data from both experiments confirmed the impact of wheel traffic (Fig. 4). In Experiment I, row position effects were confounded with ridge effects. Statistical analyses confirmed that oat yield was significantly lower for the rows with wheel traffic than the rows without it. N fertilizer application after oat emergence in Experiment II may have further reduced yield for the rows in the wheel tracks. Besides increased soil



Grain yield with the same letter did not differ significantly within each strip (LSD 0.05)

+, *, **, ***
Least significant difference (LSD) and significant contrasts for each crop.
Significant at the 0.05 and 0.01 level of probability. Tested contrast: In corn and soybean strips 1 vs 5; 1,5 vs 2,3,4; 2 vs 4; 3 vs 2,4; and in oat strips 1 vs 3; 1,3 vs 2.

Figure 3. Corn, soybean, and oat yield (Mg/ha) as affected by row position within each strip, for Experiment II.

compaction, the plants were trafficked and may have lost early season leaf area in this operation. For both experiments, oat yields in the border positions were unaffected by either bordering crop.

Pendleton et al. (1963) suggested that the center rows in four or six row strips experience border effects that influence yields. Under most conditions these effects increase yields over those found in large fields, especially for corn. Both the results of Pendleton et al. (1963) with a corn and soybean strip intercropping system and the yields in this study suggest that strip intercropping has higher production potential than conventional monocrop schemes. This seems particularly true for corn and oat, which had enhanced border yields when rainfall was adequate.

Soybean yield patterns are more complex and tend to be lower in at least one border row than in center rows. With inadequate rainfall, soybean bordering the oat strip suffered reduced yield, while adequate rainfall resulted in lower yield next to the corn strip than in the strip center. Radke and Hagstrom (1976) suggested that all soybean row yields may be affected by microclimate changes induced by the corn strip. Those closest to the corn may be reduced, while those two to seven rows from the corn may be increased.

Many questions remain unanswered regarding this system. How does the system influence soil and water conservation? The life cycle of small grains, specifically the early harvest, provides an opportunity for growing forage legume cover crops, thus allowing nitrogen fixation for the fol-

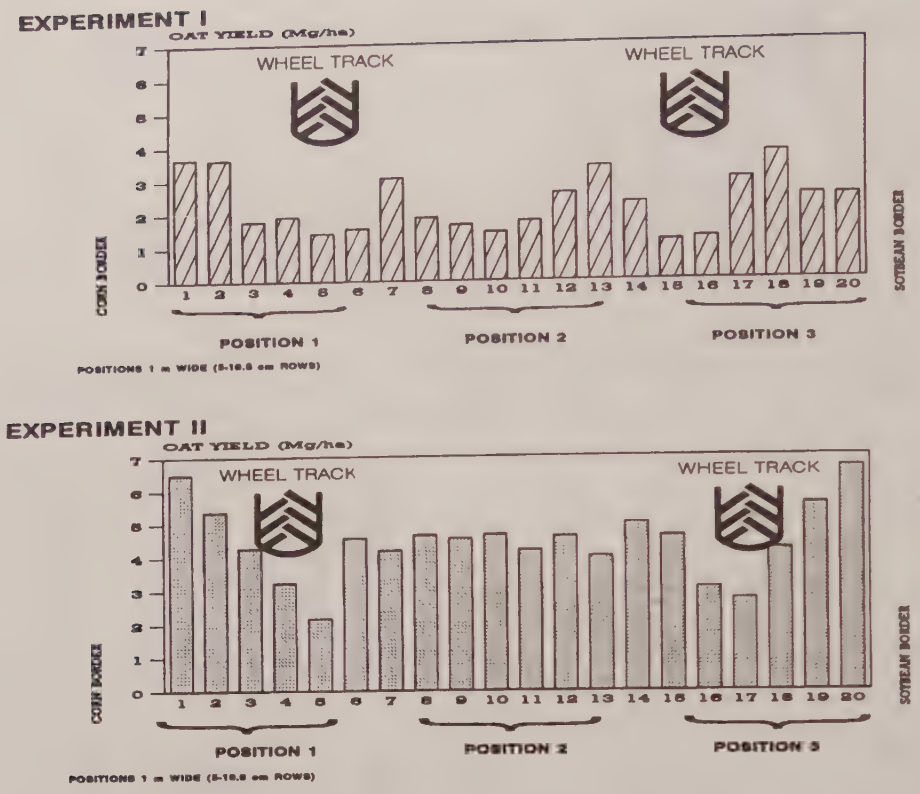


Figure 4. Individual row grain yields for oat/legume strips at both experiments in 1990.

lowing corn. Which forage legumes are best for this system, how do they affect N fertilizer needs, and are these needs different for each row? Several farmers in Iowa using the system reported it is manageable. However, will farmers adopt such a system on a large scale, and what other alternative crops can be introduced? Strip intercropping uses crop rotations, which Crookston et al. (1991) have identified as important for maximizing production. However, we do not know how much of the observed crop response is due to crop rotation and how much is due to the cropping configuration. The direction of strips is imposed by topography; however, the direction and orientation will influence the microclimate experienced by each crop and therefore will affect yields. Characteristics of this system seem to favor sustainability by diversification of crops, although many management questions still must be answered.

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RESOURCES

North Carolina Insight, a quarterly magazine published by the North Carolina Center for Public Policy Research, has published a special double issue devoted to analysis of state pesticide regulation. According to a survey of state pesticides programs done for the magazine, at least 35 state groundwater testing or monitoring programs have detected pesticides in their groundwater. The 42-question survey was completed by 45 states, 41 of which reported they had a program for monitoring or testing groundwater for pesticide contamination. Of the 45 states, 27 have banned or restricted the use of any pesticide beyond federal requirements.

The comprehensive survey, which examined the breadth of responsibilities and extent of regulatory powers of each state program, included questions in nine categories: general information, licensing and certification, record keeping, environmental concerns, farmworker safety and health, administration, regulatory authority, aerial application of pesticides, and miscellaneous information.

Asked which topics were included in the state's pesticide applicator training or education program, 43 of the 44 states responding said they included health and safety issues and integrated pest management; 39 included pollution prevention; 35 included alternatives to chemical pesticides; 31 included biological pest controls; and 6 included organic farming.

Included in the magazine were articles examining the scarcity of pesticide usage information, an integrated pest management course for farmers, and recommendations for state regulation of pesticides. Copies of *North Carolina Insight* are $14.75 from N.C. Center for Public Policy Research, P.O. Box 430, Raleigh, N.C. 27602; (919)832-2839.

Thompson On-Farm Research, with Wallace Institute, 1994 Report describes in detail the sustainable farming research being done at the Thompson Farm in Boone, IA. The research, which is partially funded by the Wallace Institute, includes "successes and failures" in several areas: fertility, cover crops, weed control, water quality-soil health, economics, and livestock. Included in the 1994 report are the results of that research, summaries and recommendations, graphs and tables, and a chapter on farming for better communities. The research report is $10 from Thompson On-Farm Research, 2035 190th Street, Boone, IA 50036-7423; (515)432-1560.

From the Ground Up, a 30-minute educational video and teachers' guide, is $85 from Green & Growing, 507-63 Albert Street, Winnipeg, Manitoba, Canada, R3B 1G4; (204)957-1092.

Sweet Corn IPM: Insect Management, a 30-minute video, is $15, payable to University of Massachusetts, from Bulletin Center, Thatcher Way, University of Massachusetts, Amherst, MA 01003.

Clean Water and Agriculture, an education packet prepared by Minnesota Rural Futures and the Minnesota Project, is $5 from The Minnesota Project, 1885 University Ave. West, #315, St. Paul, MN 55104; (612)645-6159.

Everything You Always Wanted to Know (But Really Weren't Sure Who To Ask) About Using Row Cleaners, Zone Tillage, No-Till Coulters, Special No-Till Management Report No. 6, is $6.95 from Lessiter Publications, P.O. Box 624, Brookfield, WI 53008; (414)782-4480.

Sustainable Agriculture: Definitions and Terms (SRB 94-05) and *Sustainable Agriculture in Print: Current Books* (SRB 94-06) are available from Alternative Farming Systems Information Center, National Agricultural Library, Room 304, 10301 Baltimore Blvd., Beltsville, MD 20705-2351; (301)504-6559; e-mail, afsic@nalusda.gov

Drip Irrigation and Nitrogen Fertigation Management of Vegetable Crops, a video, is $20 from Debbie Scott or Casey Walsh Cady, Fertilizer Research and Education Program, California Department of Food and Agriculture, 1220 N Street, Sacramento, CA 95814; (916)653-5340 or (916)654-0574.

A *video and brochure on composting dead poultry* are $12 per set from Polk County Soil and Water Conservation District, Poplar Street Office Bldg., Rt. 1, Box 488, Benton, TN 37307; (615)338-4010.

Energy and economic savings from the use of legume cover crops in Virginia corn production

D.R. Ess, D.H. Vaughan, J.M. Luna, and P.G. Sullivan

Abstract: *Energy analysis provides a measure of the effectiveness of sustainable agricultural systems in reducing inputs purchased from off-farm sources. This study compares the total (direct plus indirect) energy costs of growing corn for silage using manufactured N fertilizer or N-fixing legume cover crops. The cover crop either was killed with herbicide in a no-till system or disked in the spring. Economically competitive alternative crop production practices are identified.*

In both the no-till and the disked versions, cover-cropped treatments used about half as much energy per hectare as the corresponding winter fallow N-fertilizer treatments. Using vetch to provide N significantly lowered energy use per unit of crop output compared with the N-fertilized treatments. For the treatments that used hairy vetch, either alone or in combination with bigflower vetch, net revenue was statistically equivalent to that of standard-practice treatments in each year of the study.

Key words: legumes, nitrogen fertilizer, vetch, no-till

Introduction

Energy inputs to manufacture N fertilizer make it the most energetically costly input in nonirrigated production of corn (*Zea mays*) (Fluck and Baird, 1980). Forty years of steadily rising application rates have resulted in corn production consuming 44% of all directly applied fertilizers (i.e., containing primarily a single nutrient) in U.S. agriculture (National Research Council, 1989). The average N application rate on corn was 140% greater in 1985 than in 1964 (U.S. Dept. of Agriculture, 1992). Although the figure has declined since 1985, fertilizer remains the largest cash expense for a corn farmer in the Southeast (Virginia Agricultural Statistics Service, 1993). High energy and economic costs make N fertilization an excellent candidate for examination in the search for more sustainable production systems.

Energy analyses of crop production in the United States have illustrated the relationship between increased energy inputs and increased crop yields. In response to the energy crisis of the early 1970s, Pimentel et al. (1973) analyzed energy use in corn production in the U.S. for the period 1945 to 1970. N fertilizer alone accounted for 32% of the energy budget for corn production in 1970. Furthermore, the energy efficiency of corn production, expressed as the ratio of the energy in the corn to the energy required to produce it, declined by 24% between 1945 and 1970.

Smil et al. (1983) contended that U.S. agriculture in 1945 was in transition from traditional, labor-intensive, organic farming to modern agricultural methods. They compared corn production in 1954 to that of 1974, and in contrast to Pimentel et al. (1973) concluded that the energy efficiency of U.S. corn production had remained almost the same over two decades. Increased use of fossil energy resources, both as fuels and as feedstocks for other inputs, was a crucial factor in the large increase in corn production in the decades before the energy crisis. Both the Smil and Pimentel groups perceived the great potential for energy conservation in modern, high-input agriculture.

Fluck and Baird (1980) outlined seven methods for reducing fertilizer consumption without reducing crop output. One was the substitution of manures, cover crops and legumes for manufactured fertilizers. Substitution of legume-supplied N for manufactured N potentially saves 15,000 MJ/ha (Pimentel et al., 1973; Buffington and Zar, 1977), mainly in natural gas. Natural gas is used both as a feedstock and a fuel source in N fertilizer production. It accounts for about 98% of the total energy consumed in the production of ammonia, the starting material in the manufacture of most N fertilizers (Bhat et al., 1994).

Reduced consumption of manufactured N fertilizer benefits the environment by reducing CO_2 inputs to the atmosphere. CO_2 is released in the manufacture of N fertilizers, but it is consumed during the growth cycle of N-fixing cover crops.

That legume cover crops can contribute a considerable amount of N to cropping systems is well documented (Mitchell and Teel, 1977; Frye et al., 1985; Heichel, 1987; Ott and Hargrove, 1989; Duck and Tyler, 1991). The atmosphere is the source of almost all N in the soil-plant-animal system (Walton, 1983). Dinitrogen (N_2) from the atmosphere may be fixed by *Rhizobium* bacteria that exist in mutually beneficial, symbiotic associations with leguminous crops such as beans, vetches, and clover.

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Methods

This study examined the potential of legume cover crops to reduce energy requirements in corn production. The energy and economic analyses used results on inputs and yields in corn silage production from two seasons of research by Sullivan (1990). Treatments that provided N using vetch, either alone or intercropped with rye (*Secale cereale*), were compared with conventional treatments receiving manufactured N. Both no-tillage and reduced-tillage corn production were examined.

The energy analysis reported here (based on Ess, 1990) used Mudahar and Hignett's (1987) fertilizer energy requirements, Doering's (1980) method for accounting for energy embodied in farm machinery and repairs, and Green's (1987) estimates of energy inputs for herbicides. Heichel (1980) addressed the benefits of quantifying accurately the energy costs of propagating agricultural crops, an important aspect of systems that rely on legume-derived N. To meet the need for accurate energy costs for seed production, Ess (1990) analyzed each type of seed in this study.

The system boundary for the energy analysis included field operations from primary tillage through harvest. No consideration was given to storage, processing, or use of the harvested crop. Since the corn was not assumed to be used as an energy feedstock, the issue of whether the energy produced exceeds the energy consumed in production (net energy yield) was not relevant.

The analysis included both direct and indirect energy inputs, the latter entering the production process as various intermediate materials (Smil et al., 1983). The inputs covered were: corn and cover crop seeds, fertilizers, machinery, herbicides, and labor. The analysis included the energy required to discover, recover, refine, store, distribute, and market diesel fuel, a direct source of energy (Bullard et al., 1976).

The field operations in the analysis were those done in producing corn silage on the research plots. However, the machinery used in the field research was not of the size typically used in full-scale farming operations. To assess accurately the energy and economic costs faced by Virginia corn producers, a hypothetical machinery complement was developed. We used retail sales data to determine a realistic tractor size for row-crop operations, and implements were properly matched to the selected tractor. The hypothetical machinery complement enabled us to estimate the indirect energy in machinery manufacture and repairs, the direct and indirect energy consumed as fuel, and indirect energy in labor for field operations.

We assessed machinery and labor energy costs on a per-hour basis, prorating the total energy used to manufacture each machine over its estimated life (ASAE Standards, 1990). The time required to complete a given field operation allowed us to convert this to energy costs per hectare. This approach allowed comparisons of treatments differing in machinery, number of operations, or machine operation rates. Fuel consumption was also estimated for each operation and converted to a per-hectare basis. Actual quantities of fertilizers, herbicides, and seeds used in the field research were the basis for estimating the corresponding direct and indirect energy costs. Energy cost coefficients are provided in Table 1.

The economic analysis provided another comparative measure of the performance of each corn production system. Prices for fertilizers, herbicides, fuel, and seeds were obtained from local retail suppliers. The price of labor was established from regional farm wage rate data (Virginia Agricultural Statistics Service, 1993). Retail prices for farm machinery were obtained from local suppliers, product manufacturers, and published sources (North American Equipment Dealers Assoc., 1990). Input prices are summarized in Table 1.

Fixed and operating costs for each item of the hypothesized machinery complement were estimated on a per-hour basis (Chen and Bateman, 1988), using straight line depreciation with no salvage value to compute the fixed cost. Capital costs were based on the average value of each piece of equipment over its lifetime. Estimates of total machine life, costs of repairs and maintenance, and fuel consumption were based on data and models developed by the American Society of Agricultural Engineers (ASAE Standards, 1990).

Gross revenues for each treatment were calculated from actual yield data, using a value of $27.56/Mg for corn silage at 40% dry matter content (B.R. McKinnon, Research Associate, Dept. of Animal Science, VPI&SU, private communication, 1992). Costs for all items included in the economic analysis were subtracted from gross revenue to yield net revenue for each treatment, which was the basis for comparing economic performance. Costs associated with land rental or ownership were assumed to be constant among treatments and were not included.

Energy expenditure and net revenue values from each treatment were analyzed using analysis of variance procedures (SAS Institute, Inc., 1989). (Plot-to-plot variation in these variables within a treatment arose from yield variations; energy use per ha was constant within a treatment.) Multiple comparison tests were performed to reveal differences among treatments. A conservative test, Tukey's Range Procedure, was employed to ensure that Type I experiment-wise error rate was controlled (Ott, 1988; Lentner and Bishop, 1993). (Type I errors result when two means are called significantly different when they really are equal.)

A treatment had to meet two criteria to be considered superior: 1) its energy input per unit crop output had to not differ statistically from the best (lowest) value among all treatments; and 2) its net revenue had to be competitive with that of the standard treatments, that is, not differ statistically from it.

Experimental Design

The data analyzed here are from a study reported in more detail by Sullivan (1990). Sullivan examined the potential of rye and vetch cover crops to reduce corn N fertilizer requirements and provide ground cover in the mid-Atlantic region. The project was established at VPI&SU's Whitethorne Research Farm in Montgomery County in summer, 1987.

The research site initially was in a pasture sod of tall fescue (*Festuca arundinacea*) and white clover (*Trifolium repens*) and was being grazed by cattle. The land had been in pasture for three years and had grown corn before that. Some residual ni-

Table 1. Production input cost coefficients.

Item	Energy Coefficient (MJ)	Economic Cost ($)
Seed		
Hairy vetch	36.8/kg	1.92/kg
Bigflower vetch	64.9/kg	9.92/kg
Rye	16.6/kg	0.25/kg
Corn	15.5/kg	2.41/kg
Herbicides		
Atrazine	205/kg	2.62/L
Bentazon	465/kg	15.85/L
Metolachlor	297/kg	15.32/L
Orthoparaquat	493/kg	9.07/L
Crop oil	45/kg	1.37/L
Fertilizers		
Ammonium nitrate	73.6/kg N	215.00/Mg
Phosphorus	14.1/kg P_2O_5	—
Potassium	11.6/kg K_2O	—
Blended (0-25-25)	—	186.00/Mg
Application	—	11.10/ha
Machinery		
Tractor, 85 hp	319,400	30,480
Disk harrow, 3.96-m	123,900	5,090
Power harrow, 3.56-m	87,400	9,900
Planter, 4-row	77,800	9,400
No-till planter, 4-row	107,400	10,400
Grain drill, 3.66-m	83,400	4,670
Broadcaster, pull-type	74,200	4,900
Sprayer, mounted	24,300	2,000
Forage harvester, 2-row	136,800	19,180
Diesel fuel	46.4/L	0.20/L
Labor	57.1/h	5.00/h
Limestone	0.8/kg	26.46/Mg

trate (15 to 34 kg NO_3-/ha) was present in the top 15 cm of the soil profile.

The field experiment had four randomized, complete block replications. Two tillage treatments, disk and no-till, and five cover crop treatments made up a 2×5 factorial arrangement for studying cover crop N production. Two additional treatments were added to the experiment to serve as "standard practice" controls: a winter fallow treatment in which corn received 140 kg N/ha under disk tillage; and a no-till treatment with a rye cover crop, again with corn receiving 140 kg N/ha. (The names of the tillage treatments refer to the operations associated with corn planting.) The N fertilization rate for these standard practice treatments was the recommended value for corn silage according to the residual N in the soil profile measured at the start of the experiment. No fertilizer was applied to the cover crops.

Plots were 3.66 m wide (4 corn rows) by 15.2 m long. Site preparation included application of dolomitic limestone at 4500 kg/ha to adjust soil acidity. Plots were chisel plowed and disked. A seedbed was prepared for the cover crops by field harrowing with a Lely Roterra.

Cover crop treatments were pure stands of rye, hairy vetch (*Vicia villosa*), bigflower vetch (*V. grandiflora*), and two mixtures of these species. A grain drill was used to plant the cover crops. Seeding rates for pure stands were 100 kg/ha for rye and 28 kg/ha for the vetch varieties. The mixture of rye and hairy vetch was planted at 50 kg/ha of rye and 18.75 kg/ha of hairy vetch. The two-vetch mixture was planted at 18.75 kg/ha of hairy vetch and 9.25 kg/ha of bigflower vetch. Northrup King 'SS2'rye, an unbranded hairy vetch, and 'Woodford' bigflower vetch were planted. In the second year, 'Abruzzi' rye was substituted for the Northrup King variety because of the former's superior cold tolerance.

Fall-planted cover crops were killed in the spring either by disk incorporation or by desiccation with paraquat. Disked plots were worked 2 to 3 weeks before herbicides were applied on no-till plots to allow initial decomposition of the cover crop and to compensate for poor synchronization between legume N release and corn N uptake. Field harrowing with a Lely Roterra was done to prepare seedbeds in the disked/fallow treatments. P and K fertilizers were applied at rates of 56 kg P_2O_5/ha and 56 kg K_2O/ha over the top of cover-cropped and fallow plots before disking or herbicide killing. All plots were sprayed with metolachlor at 1.68 kg a.i./ha and cyanazine at 1.68 kg a.i./ha; the no-till treatments also received orthoparaquat at 0.42 kg a.i./ha. The herbicides were tank mixed.

Pioneer 3233 corn was planted at a target population of 50,000 plants/ha. Skips were replanted in an attempt to achieve the target population and a uniform stand in all treatments. N fertilizer was applied as prilled ammonium nitrate (NH_4NO_3) to the standard practice treatments in equal split applications. The first application was made about one week after planting, the

second application when the corn was about 50 cm high.

Corn was harvested for silage at 35 to 42% dry matter. Subsamples were oven dried, with yields reported as dry matter per hectare. The experiment was run for two complete cropping sequences: cover crop followed by corn on the same plots.

Results

Yields

In year one, yields in the hairy vetch and two-vetch no-till treatments exceeded that of the standard-practice no-till treatment (Fig. 1). However, all alternative-practice no-till yields were lower than standard-practice yields in the second year. The bigflower vetch treatment was the only no-till treatment whose yield increased in the second year. No-till treatments that included rye had significantly lower yields than the standard practice in the second year.

The alternative-practice disked treatments that used only legume cover crops (no rye) all exhibited yield improvements from year one to year two, but the disked treatments with rye suffered severe yield declines. The standard-practice treatment had the second lowest yield of any disked treatment in year one, but the highest yield of any disked treatment in year two.

The uptake of residual soil N by all crops during the 1988 season and the immobilization of legume-supplied N by rye are suspected to be major contributors to the yield reductions. Rye grown as a cover crop or as a component of a cover crop mixture contains a high C:N ratio (>30:1) (Sullivan, 1990). A high C:N ratio inhibits decomposition and the subsequent release of N (Walton, 1983).

Energy use

Fertilizer and fuel were the largest energy use categories in all treatments except those that used pure stands of bigflower vetch, for which the energy cost of seed was slightly greater than that of fertilizer. Energy for machinery and labor were small components of total energy consumption. Because the machinery complements and the field operation times were similar among treatments, differences in machinery and labor energy costs were inconsequential.

Cover-cropped treatments had a significant energy advantage over the standard-practice treatments. Cover-cropped no-till treatments required an average energy expenditure of 9,026 MJ/ha, compared with 19,763 MJ/ha for the standard-practice no-till treatment using a rye cover crop and 140 kg N/ha. Cover-cropped treatments that used disking to kill the cover crops required an average of 9,781 MJ/ha. The standard-practice winter-fallow treatment with 140 kg N/ha required a total of 18,488 MJ/ha. A summary of energy analysis results is presented in Fig. 2.

The no-till treatments, which relied on herbicides to kill the cover crop, required less energy than treatments that used disking. No-till treatments required more energy for herbicides, but less for machinery, fuel, and labor.

The standard-practice no-till treatment required more energy for fertilizer, machinery, fuel, and labor than did the cover-cropped no-till treatments. The standard-practice fallow-disked treatment required

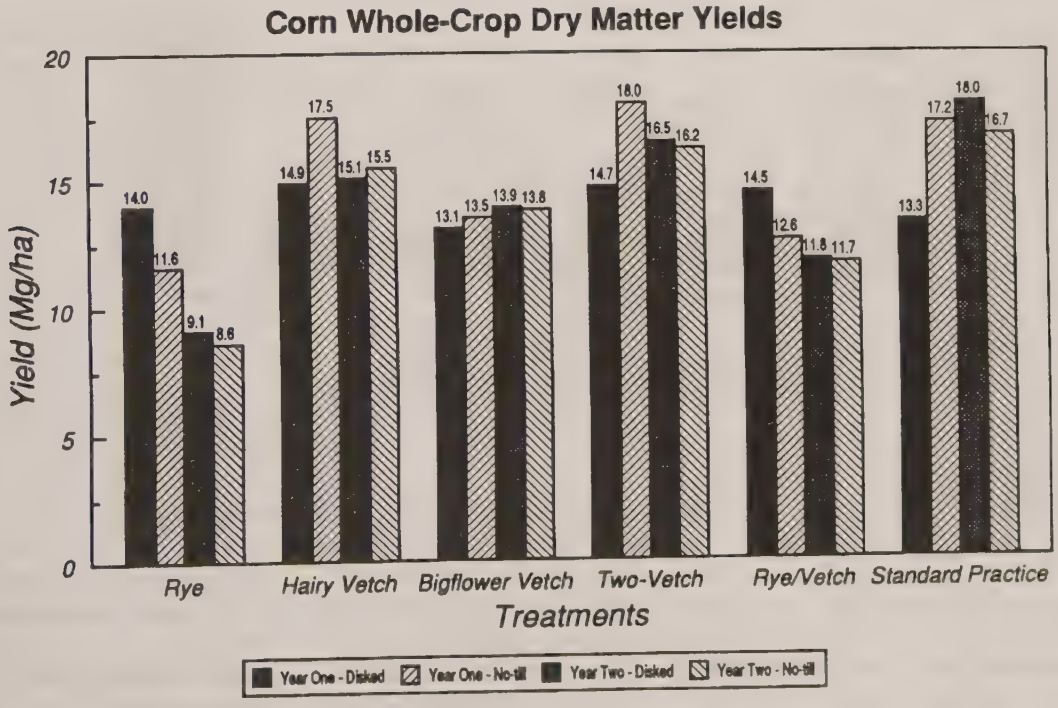

Figure 1. Corn whole-crop dry matter yields.

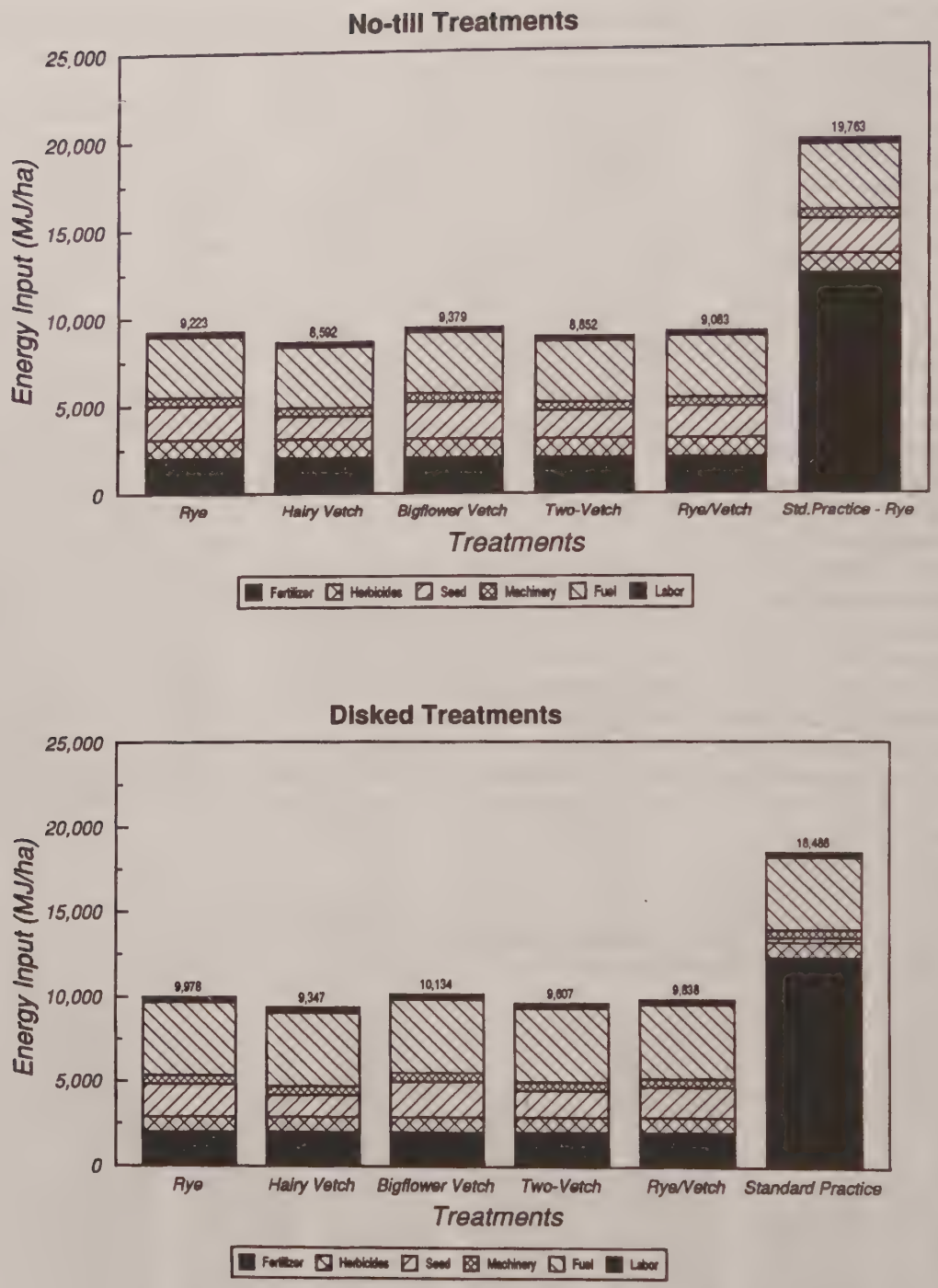

Figure 2. Energy analysis results.

more energy than the alternative treatments for fertilizer, but less for seed, machinery, fuel, and labor because of not having to produce a cover crop. In fact, energy for N fertilizer in the standard-practice treatment by itself exceeded total energy use for any alternative treatment.

In terms of energy input per unit of crop output, all cover-cropped treatments performed significantly better than either standard-practice treatment in year one (Table 2). In year two, the four best performers from year one remained the best, while the performance of all treatments that included rye declined. (Recall that yields of treatments that included rye declined from year one to year two.)

Economic performance

The economic returns of each corn production treatment were calculated to show whether the alternative treatments that pro-

duced significant energy savings could be recommended over standard-practice treatments. Unless they can be expected to be profitable, there is little chance that alternatives to standard practices will be adopted.

Potential users of alternative corn production practices have their own standards of economic performance. The only costs included in our economic analysis were those associated with direct inputs, and the only benefit was revenue from crop output. The comparisons of the low-input alternatives and the standard practices were based on short-term performance. Other benefits from the use of cover crops grown in rotation with corn, such as reduction in weeds and insect pests, reduced soil erosion, and increased soil organic matter, are of real value but are very difficult to quantify. Short-term studies of yield differences underestimate the long-term benefits of alternative practices.

In year one, the three highest net revenue performers were no-till treatments (Table 3). The alternative no-till treatment using hairy vetch as the sole cover crop had the best economic performance, followed by the two-vetch treatment. Although not statistically different, the standard-practice no-till treatment produced two and one half times the net revenue of the poorest performer, the disked treatment that used bigflower vetch as a source of nitrogen. High seed cost and moderate yields accounted for the poor showing of both the disked and the no-till bigflower vetch treatments. The alternative-practice disked treatment that included only a rye cover benefitted from the combined effects of low production costs and residual nitrogen to give a return that exceeded the average by almost $40/ha. It surpassed the standard-practice disked treatment by over $100/ha.

In year two, net revenue declined in all treatments that included a rye cover crop component. Except for the bigflower vetch treatment, all no-till treatments performed worse than in year one. By contrast, the economic performance of the three alternative-practice disked treatments with legume-only cover crops improved. The standard-practice disked treatment that used no winter cover crop and received 140 kg N/ha from ammonium nitrate improved after a poor performance in year one, producing the highest net revenue among all treatments.

Considering only inputs analyzed in this study, fertilizer costs accounted for an average of 14% of alternative-practice crop production costs, but 34% of the standard-practice production costs (Fig. 3). The standard-practice treatments, therefore, are more vulnerable to production cost fluctuations induced by fertilizer price fluctuations.

Table 2. Energy expenditures of corn silage production treatments.

Treatment	Energy Expenditure (MJ/Mg)	
	Year 1	Year 2
Rye, no-till	794c[1]	1076ab
Hairy vetch, no-till	547de	562d
Bigflower vetch, no-till	705cd	691cd
Two-vetch, no-till	495e	552d
Rye/vetch, no-till	724cd	785cd
Rye, disked	718cd	1113a
Hairy vetch, disked	627cde	629cd
Bigflower vetch, disked	779c	735cd
Two-vetch, disked	664cde	592cd
Rye/vetch, disked	680cde	836bc
Standard practice, no-till	1154b	1196a
Standard practice, disked	1392a	1032ab

[1] Values in a column followed by the same letter are not significantly different by a Tukey Studentized Range (HSD) Test ($p<0.05$).

Table 3. Net revenue performance of corn silage production treatments.

Treatment	Net Revenue ($/ha)	
	Year 1	Year 2
Rye, no-till	434ab[1]	224c
Hairy vetch, no-till	813a	672a
Bigflower vetch, no-till	307b	332bc
Two-vetch, no-till	771a	646a
Rye/vetch, no-till	476ab	415bc
Rye, disked	596ab	260bc
Hairy vetch, disked	635ab	643a
Bigflower vetch, disked	285b	340bc
Two-vetch, disked	544ab	672a
Rye/vetch, disked	612ab	423b
Standard practice, no-till	719ab	688a
Standard practice, disked	494ab	821a

[1] Values in a column followed by the same letter are not significantly different by a Tukey Studentized Range (HSD) Test ($p<0.05$).

Conclusions

Energy expenditures in corn production treatments that used cover crops to provide N were significantly lower than those of treatments that relied on manufactured N

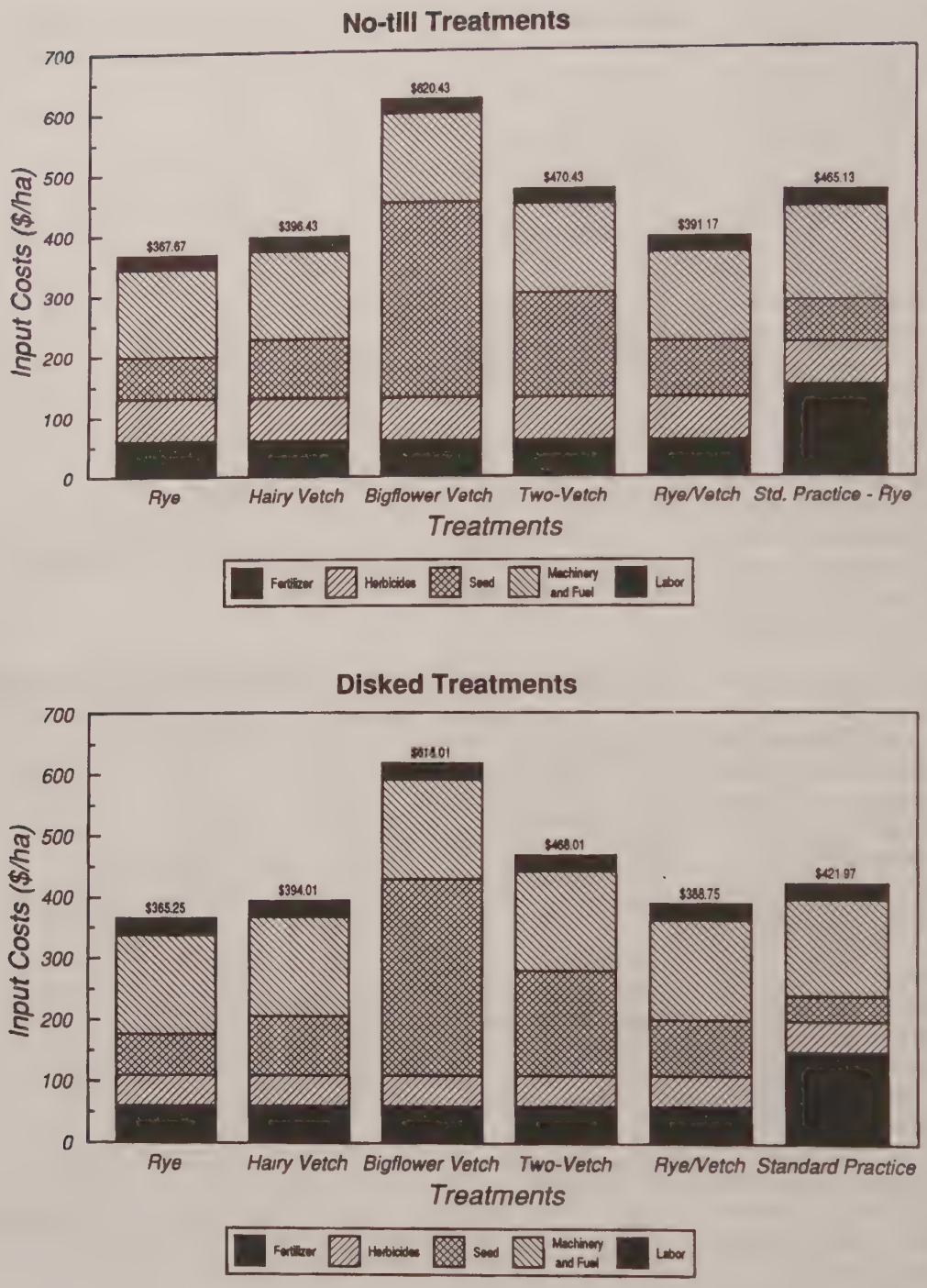

Figure 3. Corn silage production input costs.

fertilizer. Use of certain legume cover crops to replace manufactured N fertilizer in corn production is both energetically advantageous and economically sound.

On the basis of these short-term results, four alternative practices can be recommended to the farmer who prefers to produce corn using N that originates on the farm. Using hairy vetch or a mixture of hairy vetch and 'Woodford' bigflower vetch as winter-annual cover crops in no-tillage and reduced-tillage systems can provide enough N for economically competitive corn silage production. The potential profitability of these practices equalled that of two "standard" corn production practices requiring a considerable amount of manufactured N fertilizer. Positive yield trends for the reduced-tillage hairy vetch and two-vetch treatments enhance their competitiveness.

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Herbicides Contaminate Drinking Water for 14 Million People, Study Says

Fourteen million people in 15 states routinely drink water contaminated with five major agricultural herbicides, according to a study released recently by the Environmental Working Group and Physicians for Social Responsibility. The study examined the use and contamination of five herbicides: atrazine, cyanazine, simazine, alachlor, and metolachlor. Each spring, farmers apply more than 150 million pounds of these herbicides to corn and soybean fields, according to the report. The report found that 11.7 million of the people drinking contaminated water lived in the states of Illinois, Indiana, Iowa, Kansas, Kentucky, Louisiana, Michigan, Minnesota, Missouri, Nebraska, and Ohio. The other 2.4 million people found by the report to be drinking contaminated water were in the District of Columbia, Maryland, Pennsylvania, and Virginia.

"As a result," the report said, "more than 3.5 million people in 120 cities and towns face cancer risks that are 10 times to 100 times higher than the federal benchmark, based on average annual exposure to these herbicides in drinking water." The report analyzed results of tests on 20,000 samples taken by state and federal investigators from treated tap water, rivers, and reservoirs that are drinking water sources. *Tap Water Blues* is $43 from EWG, 1718 Connecticut Ave., NW, #600, Washington, D.C. 20009; (202)667-6982.

Communicating between farmers and scientists: A story about stories

Connie and Doc Hatfield, Preston and Wanda Boop, and Ray D. William

Ranching in the 1990s involves vivid word pictures with emotions, learning, a bit of humor, and fierce independence, explained Connie, as students and resource specialists sat on hay bales in a small barn on the high desert in central Oregon. Rangeland Resource students listened, a high school English teacher listened, an Extension horticultural specialist listened, and a Bureau of Land Management ecologist listened along with the professor. A wagon wheel stood near a rusty bucket of sagebrush and bunchgrass. Doc contributed short stories, a few facts, and his perspective of the same events. As she continued, Connie looked toward Doc and wondered whether her story was pitched at about the right level of emotion; was she effectively describing their ranching experience in the 1990s? He smiled under a large grey cowboy hat as his boot rested on the wagon wheel. Everyone felt the tension. Inviting environmental advocates to their ranch ... was this wise?

Many experiences later, Doc says they have regained independence through collaborative learning with urban dwellers and consumers of their beef products. They welcome people with open minds toward learning. Their vision includes cattle, fish, and wildlife; the 7 inches of rain or snow that falls in winter and must be captured to sustain fish and urban dwellers in August; and sharing beliefs and values about the landscape while fish, grass, and ranchers survive.

Connie and Doc Hatfield are ranchers in Brothers, OR 97712; Preston and Wanda Boop are farmers in Mifflinburg, PA 17844; Ray D. William is Extension Specialist, Dept. of Horticulture, Oregan State University, Corvallis, OR 97331.

In response to Connie's stories, organizers of the 1993 Farming Systems Research and Extension (FSRE) symposium invited 15 farmers to "share their experiences and stories." During the opening session, participants experienced the drama of collaborative learning in central Oregon. Connie recounted how she had been concerned about what environmental advocates might look like and how they would act. She described learning about baby ducks and how she and Doc had changed their grazing practices to improve cover and habitat for ducklings near the pond. As these urban visitors shared their knowledge and concerns about ducks, birds, fish, and much more, Doc shared ranchers' experience in learning and building trust. They concluded that ranching involves butterflies, water, cows, calves, people, grass, stewardship, ducks, ducklings, customers, and a vision with feelings for the land and people. Participants and listeners struggled with their own feelings about these relationships.

In the evening, a story-telling event was organized (scientists preferred to describe the event as "sharing experiences"). Several farmers shared their stories, their dreams, and their practices. The event was so popular among farmers that they requested another session Friday evening. Following both events, people continued telling mini-stories in numerous small groups. One farmer described this as the "buzz" factor or a non-traditional way of measuring interaction and learning.

Preston and Wanda shared their enthusiasm for farming. Elder family members had encouraged them to farm while Preston remodeled their homes. Soon, a neighbor unloaded 600 tons of poultry manure, which resulted in a composting business. Next, the county began dropping fifteen to twenty loads of leaves each fall, which required compost mixing equipment. Meanwhile, they've learned to think in different ways, to manage their integrated crop/livestock enterprise, and to sell organically grown products. Their story seemed like a comedy of successes. They shared a contagious enthusiasm for learning.

During the second story-telling session, farmers asked the research and extension participants to tell their stories. One scientist helped participants visualize research involving monocropping that didn't resemble farmer's mixed cropping systems. When he inquired, farmers showed logic and common sense regarding mixed cropping practices. Another scientist described his transition from extension to research and back to applied research. He shared his reasons with a bit of humor and humility. A farming systems researcher from Asia described application of vegetable gardening practices with 57,000 rural families in Bangladesh. An extension specialist told how he asked 40 producers in Oregon "what are your problems?" instead of "what are your weed problems?" The producers responded quickly that government regulations, environmental/societal issues, regulations, international free trade, and more regulations were making them very anxious.

Suddenly, Doc jumped forward and exclaimed that he understood the FSRE practitioners' values and interest in developing relevant research with a strong on-farm or farmer participatory component. Apparently, they had taken off their professional masks, expressed their sense of commitment, and described their emotions about FSRE in collaboration with farmers and ranchers.

During the final day, farmers and the other participants began to imagine what would happen if a professional program started with story telling. People might share their personalities, their reasons for participating, their emotions, and their sense of humor. Preston asked how to encourage discussion and "buzz" throughout the symposium. Doc kept adding suggestions that included asking the right question and encouraging everyone to share their experience and knowledge. Scientists considered meeting with farmers' organizations or including farmer in the organizational name of FSRE. Enthusiasm and learning continued until attendees dispersed on airplanes like the spokes of that wagon wheel on the high desert in Oregon. Perhaps learning continued among people who shared their stories, their connections, and their emotions for the land, its people, and its critters.

Thus story-telling provided a way for farmers, ranchers, and scientists to communicate.

Stories are about people;
ranchers, farmers, educators, and citizens.
Stories are about sharing;
experience, emotion, tension, and learning.
Stories are about people;
denim skirts, cowboy hats, farm families, and communities.
Stories are about communicating;
the smell, the touch, the tension, and the opportunity.
Stories are about people;
sharing communicating, learning, and trusting.

BOOK REVIEWS

Future Harvest: Pesticide-free Farming. By Jim Bender. 1994. University of Nebraska Press, PO Box 880520, Lincoln, NE 68588-0520. $21, hardcover. xvii+159 pp.

This book is unique because it was written by a farmer with 20 years of practical experience who is truly passionate about seeking alternative approaches to modern, industrial-style agriculture. Jim Bender grows a wide variety of organically certified crops and raises about 100 beef cows on a 642 acre farm in eastern Nebraska. No pesticides have beed used on the farm since 1980 and no synthetic fertilizers since 1987. He has had considerable success as well as some notable failures, which he candidly shares with the reader.

The book is reasonably short and is written in clear and concise language. The first two chapters give an overview of the current state of agriculture and provide the rationale for converting to a nonchemical production system. The author is not afraid to challenge conventional wisdom, and views a farm's reliance on chemicals as akin to a person's dependence on drugs. He makes an excellent argument for eliminating pesticides instead of merely reducing usage. He rejects the option of retaining herbicides as a bailout if nonchemical means fail because this "reduces the incentive to gain proficiency in strategies for avoiding postemergence herbicides" and because "the goal of being pesticide-free can by itself push a farmer to more and useful skills and knowledge than he or she would otherwise attain." He astutely points out that organic farming has been misunderstood because critics have failed to note its beneficial synergistic effects: "Because of the interrelatedness of the components of pesticide-free systems, often the actions taken to meet one objective also contribute to attaining others." For example, growing cover crops to prevent erosion and to add nitrogen also can provide forage for livestock and make cultivation easier by improving soil tilth.

Bender provides solid, practical advice for developing a conversion plan. He emphasizes that successful conversion must take account of the structure of the entire farm, and that it begins with an aggressive, pro-active approach to soil conservation, including permanent terraces and grass waterways. Livestock is a key component that he deals with in more detail in a later chapter. He encourages farmers to take advantage of some government programs, such as the Conservation Reserve Program. He also recognizes the need to communicate ideas and establish a dialogue among lenders, farm managers, and landowners if any real change is to come about.

The next two chapters extensively cover two aspects of farming that Bender believes are essential for successful chemical-free farming. Chapter 3 covers weed management, giving many examples from the author's own farm. Successful rotary hoeing, harrowing, and cultivating techniques are described in great detail. Bender has a refreshingly undogmatic approach to tillage, employing several methods to maintain maximum flexibility and to fulfill his agronomic, economic, and environmental goals with minimal tradeoffs. He also provides good information on specific weeds, in particular field bindweed (*Convolvulus arvensis* L.), which he considers a major problem on many farms.

Chapter 4 deals with the hotly debated issue of livestock. Here is where the author's passion comes through most clearly. He believes strongly that the separation of livestock and crops into concentrated feedlots and large cash grain farms is the central reason for the unhealthy state of modern agriculture. Although he concedes that it is not essential to include animals on an organic farm, he argues that without them it is much more difficult to achieve four central objectives of sustainable farming: soil conservation, elimination of pesticides, financial stability, and nutrient recycling. Bender refutes the claim that organic farming would require too much livestock, providing statistical facts in support. He then gives a specific example of how to organize a summer drylot beef cow-calf operation that is compatible with the different types of land typically present on a farm and that provides

adequate feed, maintains high productivity of cash grain crops, and recycles nutrients properly.

Conventional and organic farming are compared in Chapter 5, using a wide range of performance indicators. The argument for organic farming becomes very compelling when the evaluation goes beyond the simplistic measure of bushels per acre and includes soil conservation, management, and overall economic performance. The author shatters the widespread assumption that organic farming will never be accepted because conventional, chemical-based farming is easier and more convenient: "Chemical weed control creates a host of potential problems for raising row crops, ... [such as] ... crop rotation restrictions, ... small margin of error in application, herbicide-stressed crops, and application demands at the busy planting time." He admits that organic farming is not so easy either, but regards its challenges as solvable. Also, organic farming has an advantage that often is overlooked; it distributes the demand for labor relatively evenly throughout the year, whereas the work load on a conventional cash grain farm is heavily concentrated in the spring and fall.

In Chapter 6, "The Assault on Alternative Agriculture," Bender addresses very broad and profound issues relating to the structure of the modern food production and delivery system. This chapter strikes at the heart of the debate over the future of agriculture. The most often cited justifications for continuing on our present agricultural course are listed: elimination of chemicals would spell calamity; the key to pesticide safety is to follow label directions; farmers have a moral obligation to feed the world; the world is filled with risks; and alternative farming requires too much livestock. Bender then convincingly rebuts these arguments. This is perhaps the most powerful chapter because it has immediate significance for all consumers. It is well referenced and it encourages the reader to become more educated about these important issues.

This excellent book should be read by anyone who cares about our environment and about how our food is produced. It speaks to a widely diverse audience. It is technically sound, but it is clearly understandable and not filled with esoteric jargon. Admittedly, the specific examples are geared toward midwestern-style grain and livestock farming; Bender is intimately familiar with these systems and can speak about them with authority. I recommend this book highly and hope that many other articulate and knowledgeable farmers will follow Bender's example and share their visions of a healthier and more optimistic agricultural future.

Steve Peters, Research Agronomist, Rodale Institute Research Center, 611 Siegfriedale Road, Kutztown, PA 19530.

Genes, Crops, and the Environment. By John Holden, James Peacock, and Trevor Williams. 1993. Cambridge University Press, 40 W. 20th St., New York, NY 10011-4211. $49.95, hardcover; $17.95, paper. xiv+162 pp.

Can yet another book on biodiversity add to our already bountiful collection of information and statistics on the worldwide loss of genetic material? *Genes, Crops, and the Environment* provides an accessible explanation of the importance of plant germplasm for crop breeding. The book is readable for general readers and for undergraduates with or without science backgrounds. It is a valuable contribution to our broad understanding of why genetic erosion of major crop species should be of concern to us all.

The authors begin by describing genetic variation in natural ecosystems and explaining how it has been affected by the population explosion. Species always have changed, resulting in both gains and losses in genetic diversity, but never before have the changes been as rapid as those caused by the impacts of large numbers of humans on the environment. The book explains why these changes are critical to maintaining genetic options for the future.

Evolution of crop plants under human guidance is illustrated with four examples: banana, cotton, wheat, and rice. The authors describe in easily understood language the "centers of origin" concept of Vavilov and the way that landraces have been collected and used by breeders. They comment on the important work of the International Board for Plant Genetic Resources in promoting the "collection, conservation, documentation, evaluation, and use of crop plant genetic resources" and coordination of an international network of genetic resource centers. However, they neglect at this point the important work of many national research programs and the international research centers in establishing germplasm banks for major crop species. This is corrected in part in the next chapter, which mentions the more than 83 thousand samples collected and classified by the International Rice Research Institute.

A detailed discussion is given of how genes from wild species and landraces have been used in crop improvement in rice and wheat, two of the most important food crops worldwide, and in some less studied crops, such as sweet potato and sugar beet. Genetic manipulation has led to new species such as *Triticale*, and to improved cultivars of perennial species such as rubber. One justification offered for germplasm preservation is the need to maintain genetic variability as a source of future new crops to meet the demand for food and other societal needs.

Because there is such a large pool of plant genetic resources in natural ecosystems, it is difficult to decide what to collect and maintain. How many seeds or vegetative propagules should be collected, how should they be classified and stored, and how should they be made accessible? These critical issues need to be resolved at considerable expense. The authors discuss methods of storage and preservation, including sealed containers under controlled conditions and storage in the field as living plants. Procedures must be established that will insure the continuity of genetic material once it is collected and classified. Multiplication and maintenance of materials require that seeds or vegetative material be planted at regular intervals. The genetic makeup of a population always is susceptible to change, and random collection of seeds is important. The location for growing a crop to produce seed for future storage also will influence the performance of individuals and may unintentionally select plants adapted to the chosen sites.

To preserve germplasm of native landraces of crops that currently are important or that may be useful in the future is to recognize one of our most important re-

sources. The choice of materials and their classification, assured budgets and secured storage facilities, and ownership and access to global genetic resources are challenges that must be addressed. This book describes the current international efforts to preserve and describe crop germplasm for today and for the future. It includes a useful list of references and a respectable index. I recommend it to undergraduates, even those with little background in science, and I also think it will be useful as a reference in a graduate course in plant breeding.

Charles Francis, Professor, Center for Sustainable Agricultural Systems, University of Nebraska, Lincoln, NE 65853.

Challenging the Professions: Frontiers for Rural Development. By Robert Chambers. 1993. Intermediate Technology Publications Ltd., 103 Southampton Row, London WC1B 4HH, U.K. $32.50, hardcover; $6.50, paper. xvi+143 pp.

Some years ago in India I ran a training course on participatory methods with Robert Chambers in which we both were struck by the innovative critique that a farmer offered on a scientist's experiment in rice-fish culture. The farmer not only drew, with the aid of sticks, ash, seeds and dung, a new field layout, seasonal calendar and bioresource flow model, he also hypothesized that an integrated fish crop might help sustain his declining rice and wheat yields. Interestingly, neither local nor international scientists have been willing and able to pick up this hypothesis. I knew why the chickens ate up the farmer's diagrams, but why scientists would not work on the hypothesis puzzled me. In this book Robert Chambers has supplied some answers, drawing on more than twenty years of personal experience in rural development in Africa and Asia.

These answers could play a pivotal role in changing the way scientists and their managers think and act. His experience and his persuasive arguments leave little doubt that a paradigm shift is necessary for sustainable development. However, the definition of the old and new paradigms is confusing; they variously have been called core or peripheral, first or last, blueprint or learning process, and Transfer-of-Technology (TOT) or Farmer-First (FF). Adding to the confusion, these terms also are applied to approaches. These synonyms apart, no new paradigm is going to establish itself unless it becomes widely accessible for citation and peer review. Moreover, any new paradigm must enable the separation of what is "correct" from what is "incorrect." While participatory appraisals can give voice to farmers, they are infamous for their ability to mislead the instant expert. Chambers, a strong proponent of participatory appraisals, has not given us enough cautionary tales or practical hints to diminish this prospect. A nice little story late in the book recounts how an economist found that his quantitative analysis also could be misleading. Clearly, this makes a good case for complementarity between paradigms.

Chambers opens his book by drawing in broad strokes the intellectual landscape to be covered. The resulting picture of "normal" professionals and new paradigms gives the reader a feel for what has gone on in development and what it has meant for the professionals who have worked at it over the past forty years. The shift from "blueprint" to Korten's "learning process" for development is described. Surprisingly, the description fails to mention the important Hawkesbury experience with a learning process curricula.

From this modern overview the reader is brought back to earlier problems of managing rural development. Thus, Chapter Two does not address current issues of environment-poverty interactions, NGO-GO linkages, and grass roots empowerment. Still, this chapter in some ways is futuristic. Most of us are hooked on problem diagnosis, but Chambers makes some interesting points on its shortcomings. The main points are the negative connotations associated with problems, the fact that solutions promote a static situation rather than a developmental one, and the tendency of diagnosis to lead to misallocation of resources as we try to solve problems of our own making.

The drawbacks of not updating older work also show up in Chapter Three. Rather than discussing issues in selecting participatory projects, Chambers provides solutions for 1970s-style projects. Still, we do learn why participatory technology development is now necessary. But more importantly, senior civil servants and bank officials may find help in dealing with the seeming conundrum of banks needing projects that spend money and the poor needing technologies with low external inputs.

Amid all the political, economic, social and technical elements that make up project development, Chapter Four provides an important reminder that seasonality must be included in any analysis. The "hungry gaps" and "sick seasons" must be communicated to the planners. One shortcoming is that seasonality as seen from crops alone omits foods supplied by hunting, fishing, and gathering from open access resources. Nevertheless, the chapter provides a good historical background and a postscript that brings us up-to-date on the agricultural if not the health side.

The general agriculturist will enjoy most of all Chambers' description of the FF approach in Chapter Five. Indeed, the book is worth buying for this chapter alone. It takes as its point of departure the perspective that our "problem [is] less one of producing enough food in the world and more one of who grows it, where it is grown, and who has access to it." Nowadays, we might add "and how it is grown" to embrace concerns about environmental degradation. Chambers sees the critical task of agriculture as providing a decent livelihood so that the poor do not migrate to open access forest, river and coastal resources. The chapter introduces the important concept of Complex, Diverse, Risk-prone "CDR" agriculture. It provides, though a fine set of comparative tables, a nice explanation of why TOT approaches worked for "Green Revolution" (GR) agriculture and why they did not work for CDR agriculture. Stemming from this concept are two important ideas. First, while GR agriculture is reaching its sustainable production limit, CDR agriculture is well below its production potential. Second, CDR's features of complexity and diversity are attributes of sustainable systems that we might want to preserve rather than lose to GR agriculture. The challenge, therefore, is to improve CDR agriculture, for which TOT is ill-equipped. This is the best argument for a new paradigm. The challenge, however, is not just about developing research meth-

ods and farming systems, but building the new journals and textbooks, teaching methods, and professional reward systems to support the emerging paradigm. The slow rate of change in agricultural development over the last forty years only serves to show how great the challenge is.

Getting projects started right — that is, learning the complexities of the beneficiaries' circumstances — is the subject of Chapter Six. Notwithstanding a recognition of this, Chambers argues that donor bureaucrats and the experts they hire will make it difficult to get FF projects going. In their defense, Chambers' description of a "learning" project is hardly likely to inspire a minister of finance to invest. On the other hand, how can the field staff get the necessary experience without investments in projects?

Chambers sees NGOs coming to the rescue. Chapter Seven describes the role of NGOs and the important effect they can have on FF research. Indeed, NGOs are well positioned to propagate Chambers' "genes of participatory research", which include: "... critical self awareness, 'handing over the stick' (passing the initiative to villagers), 'they can do it' (having confidence that villagers can map, model, rank, score and so on), 'embracing error' (welcoming and sharing mistakes as opportunities for learning), and 'using your best judgment at all times' (stressing personal responsibility)." It is a pity that more is not said on the attitudes and skills required for good field work. Part of this "gene propagation" will be affected by training. It would have been nice to see some mention of self-learning materials, which will become more and more important.

As in the opening chapter, Chambers closes his book with a broad sketch of rural development ideology since the 1960s, as a check for readers who may be reinventing the wheel. Unfortunately, I have a suspicion that current interest in natural resource management may well lead to a resurgence of "integrated rural development" and "community-based management" style projects.

Challenging the Professions certainly does that, but is this new paradigm so fragile that its shortcomings cannot be discussed? Baskets of choices may not allow farmers to demand other interventions. There is an important difference between choosing from an array of technologies and demanding a technology that does not exist. Certainly, the voluminous descriptions obtained through participatory rural assessment rarely lead to analytic and synthetic outputs. And, certainly, putting the farmer first may not necessarily lead to sustainable farming where profits or survival are the overriding motivators. This volume is repackaging published material to make a case for a new paradigm; perhaps it is unfair to expect it also to cover the practical difficulties. One can only hope that for many this book will provide the necessary "fire-in-the-belly" to get them up and going. But, before they do, they are advised to buy the boss a copy as well.

Clive Lightfoot, Senior Scientist, International Center for Living Aquatic Resources Management, Manila, Philippines. ICLARM Contribution Number 1056.

The Real Dirt: Farmers Tell About Organic and Low-Input Practices in the Northeast. Edited by Miranda Smith and members of the Northeast Organic Farming Association and Cooperative Extension, 1994. Northeast Region Sustainable Agriculture Research Program, Hills Building, University of Vermont, Burlington, VT 05405. $13.95, paper, 264 pp.

This book, the work of many contributors, provides a broad view of northeastern organic and low-input agriculture. It is a product of the Northeast Organic and Sustainable Farmers Network, which is composed of farmers, farm organization representatives, extension agents and university researchers. The project was funded by the Low-Input Sustainable Agriculture (LISA) program, now the Sustainable Agriculture Research and Education (SARE) program. *The Real Dirt* is based on material obtained during farmer interviews. Farmers' comments are organized topically and supplemented with additional information provided by each chapter's authors.

The book nicely serves several functions: it provides an overview of how agriculture is conducted at many low-input and organic farms in New England; it provides information about a broad range of resources for farming and problem solving in New England agriculture; and it provides detailed information about strategies for dealing with many agricultural production problems, for example managing weeds (Chapter 7). The book is somewhat like a combination "yellow pages" directory and a how-to manual. I can imagine that it will appeal to many types of readers: commercial farmers who want to make the transition from conventional to organic or low-input farming; people who are thinking about getting started in farming or who are making the transition from backyard gardening to larger-scale production; and non-farmers who are interested in the detailed realities of organic and low-input agricultural production in New England. The book makes clear that a strength of organic and low-input farmers is their willingness to share information and contribute to shared successes, remarkable characteristics for people who operate competitive small businesses.

The Real Dirt is divided into six major sections, covering soils, pests, crops, livestock and dairy management, farm management and marketing, and whole-farm design. Each section is composed of several chapters, most of which conclude with bibliographies and sources for obtaining the cited publications. This enhances the book's usefulness by making it easy for readers to track down original references from many diverse publishers. Each section concludes with a few pages of comments by growers, for example, about farm system components with which they have experimented and their research needs, and by researchers, including excerpts from the reviews they offered during the book review process. The comments on growers' research needs could provide the inspiration for many future cooperative research projects. The comments sections provide some of the most interesting reading of the book.

The individual chapters are written in an informative, easy-to-read manner. Specific areas within chapters are set off by headings, and the text is interspersed with black and white photographs and drawings. The four chapters in Section One introduce the concepts of low-input and organic agriculture, describe the practices of

cover crops, green manures, and crop rotations, and discuss soil management and soil fertility. Section Two deals with pest management, including Integrated Pest Management (IPM) techniques, control strategies for some of the major pest problems that growers face, including insects, mites and mammals, weeds, and plant pathogens. Section Three contains four chapters on crop production: vegetables and herbs, small fruits, greenhouse crops, and tree fruits. The two chapters in Section Four deal with livestock and dairy management; one is on production, the other comprises case studies from six organic animal producers. Section Five contains three chapters on management and marketing, including growers' diverse opinions about charging price premiums for organically grown food, while Section Six contains two chapters on integrated farming systems and the transition from conventional to organic farming.

In addition to the information assembled from farmer interviews and researcher comments, the authors have incorporated a great deal of information from other sources. For example, Chapter Four on soil fertility from amendments includes a table on characteristics of organic fertilizers adapted from a chart compiled by Necessary Trading Co.

The book concludes with several appendices: a glossary, although some technical terms are not included (greensand, for instance); profiles describing the farmer and farm history for most of the farmers who contributed to the discussions; a list of northeast organic growers associations and certification programs; a resource directory; a list of northeast regional Cooperative Extension and IPM coordinators; a list of reviewers; and a bibliography for additional information.

Growers comments included in this book are based on their field observations and experiences with growing conditions determined by the particulars of their own farms. Readers hoping to use this book as an authoritative field guide should be aware that the reports of field phenomena are not derived from monitored field studies. Nonetheless, readers will find that the variety of opinions and observations offered in this book make stimulating reading.

Wendy Mechaber, Research Associate, Department of Biology and School of Nutrition, Tufts University, Medford, MA 02155.

UPCOMING EVENTS

January 10-12, 1995, the *1995 California Chapter, American Society of Agronomy, Annual Meeting* will be held in Visalia, CA; contact Shannon Mueller, Fresno County Farm Advisor; (209)488-3285.

January 13-15, 1995, the Southern Sustainable Agriculture Working Group will host its *4th Annual Conference and Trade Show* in Gulf Shores, AL; contact Keith Richards, PO Box 324, Elkins, AR 72727, (501)292-3714.

January 14, 1995, *Environmental Justice, Population, and the New Majority of Color* will be held al Holman United Methodist Church, Los Angeles, CA; contact EDGE: The Alliance of Ethnic and Environmental Organizations, 300 Broadway, #39, San Francisco, CA 94133; (415)421-6891.

January 14, 1995, *Gifts of Good Soil*, the 6th Annual Southern Plains Conference, will be held in Amarillo, TX; contact Darryl Birkenfeld, Southern Plains Conference, PO Box 5644, Amarillo, TX 79117; (806)364-1551.

January 16-18, 1995, *Achieving Global Human Security*, the 1995 International Development Conference, will be held in Washington, D.C.; contact Kathy Morrell & Associates, Inc., PO Box 11276, Alexandria, VA 22312; (703)642-3628.

January 23-25, 1995, the *1995 Conference on Sustainable Agriculture*, sponsored by The Council for Agricultural and Science Technology, will be held in Washington, D.C.; contact Jon Hiler, Membership & Community Services, ASAE, 2950 Niles Road, St. Joseph, MI 49085-9659; (616)428-6327; e-mail hiler@asae.org or hilerj@aol.com

January 24-25, 1995, the *16th Annual Eastern Iowa Conservation Tillage Show*, sponsored by the USDA Soil Conservation Service, will be held in Cedar Rapids, IA; contact C.W. Lawrence, Jones County Soil Conservationist, 405 East Main St., Anamosa, IA 52205; (319)462-3196.

January 25-28, 1995, *Seeds of Sustainability—Planting Our Future*, the 15th Annual Ecological Farming Conference, will be held at the Asilomar Conference Center, Pacific Grove, CA; contact Committee for Sustainable Agriculture, PO Box 838, San Martin, CA 95046; (408)778-7366.

January 27-29, 1995, the *14th winter conference of the Northern Plains Sustainable Agriculture Society* will be held in Aberdeen, S.D.; contact the Society, HC 5 Box 104, Langdon, ND 58249; (710)256-2424.

January 27-28, 1995, *Organic Agriculture: Growing the Network*, the 14th annual Organic Agriculture Conference, will be held at the University of Guelph, Ontario, Canada; contact Hugh Martin, Ontario Ministry of Agriculture, Food & Rural Affairs, (519)631-4700, or Tomas Nimmo, Canadian Organic Growers, (705)444-0923.

February 5-9, 1995, *Jazzing Up Conservation*, the National Association of Conservation Districts 1995 Annual Meeting, will be held in New Orleans, LA; contact NACD Service Center, 1-800-825-5547.

February 7-9, 1995, the *New York State Direct Marketing Conference* will be held in Batavia, N.Y.; contact Ken Silsby, Conference Chairman, (716)433-2651.

February 24-25, 1995, the *Pacific Northwest Farm Direct Marketing Conference* will be held in British Columbia, Canada; pre-conference tours will be held February 22-23; a post-conference tour will be held February 26; contact Pacific Northwest Farm Direct Marketing Association, PO Box 722, Prosser, WA 99350-0722; (509)786-1000.

February 28-March 2, 1995, the *4th International IFOAM Conference on Trade in Organic Products* will be held in Wiesbaden, Germany; **March 3-5, 1995,** *BIO FACH '95*, an IFOAM Trade Fair, will be held at the same location; contact IFOAM Trade Conference '95, Sunder & Rottner, Von-Vollmar-Str. 4, D-91154 Roth, Germany; phone, 9171-4011.

February 28-March 3, 1995, *Carrying the Torch for Erosion Control—An Olympic Task*, the 26th annual International Erosion Control Association Conference and Trade Exposition, will be held in Atlanta, GA; contact IECA, PO Box 4904, Steamboat Springs, CO 80477-4904; (303)879-3010.

March 4-5, 1995, the *13th annual conference of the Northeast Organic Farming Association of New York* will be held at Tompkins/Cortland Community College, Dryden, N.Y; contact Ammie Chickering, NOFA-NY, PO Box 21, South Butler, N.Y. 13154-0021; (315)365-2299.

April 27-30, 1995, an *International Conference on Environmental Ethics and the Global Marketplace* will be held in Athens, GA; contact Richard C. Field, Georgia Center for Continuing Education, University of Georgia, Athens, GA 30602-3603; (706)542-3063.

May 8-10, 1995, *Planning for a Sustainable Future: The Case of the North American Great Plains* will be held in Lincoln, NE; contact Dr. Donald A. Wilhite, Director, International Drought Information Center, PO Box 830728, University of Nebraska, Lincoln, NE 68583-0728;(402)472-6707;e-mail agme002@unlvm.unl.edu

June 10-13, 1995, *Environmental Challenges: The Next 20 Years* will be held in Washington, D.C.; contact the National Association of Environmental Professionals, 5165 MacArthur Blvd., NW, Washington, D.C. 20016-3315; (202)966-1500.

EPA Will Phase Out Uses of 36 Pesticides under Lawsuit Settlement

The U.S. Environmental Protection Agency (EPA) will begin phasing out uses of 36 cancer-causing pesticides as a result of an out-of-court settlement of a lawsuit that charged the agency had violated the Delaney Clause by allowing residues of carcinogenic pesticides in processed foods. The Delaney Clause prohibits the presence in processed foods of even minute amounts of cancer-causing pesticide residues. The settlement also calls for the EPA to review within five years an additional 49 cancer-causing pesticides to determine whether they should also be eliminated from certain uses. According to the Natural Resources Defense Council, the lead plaintiff of the lawsuit, the 36 pesticides and their uses include: alachlor, used on soybeans and peanuts; benomyl, a fungicide used on apples, citrus, grapes, rice, and tomatoes; captan, used on grapes, plums, and tomatoes; mancozeb, used on cereal grains and grapes; and dicofol, used on fruits and tomatoes.

"The most pronounced effect of the settlement will be to increase the pressure on Congress to enact a far-reaching new law governing pesticides," said an article in *The New York Times*. "Such an overhaul could supersede the EPA settlement." The Clinton Administration had proposed a new bill creating a less rigid standard for pesticides used in processed food, but neither that bill nor any other pesticide reform bills introduced in Congress was passed during the past session. Those proposals are expected to be reintroduced when the next session of Congress starts this year.

Concerned about Pesticides, Shoppers Seek Organic Foods, Survey Finds

In response to concern about the use of pesticides and agricultural chemicals, and the performance of the federal government in protecting consumers from those chemicals, shoppers are actively seeking out organically grown produce, according to a recent survey of food shoppers' attitudes about organic produce. The survey of 1,000 food shoppers, commissioned by Rodale Press, Inc., found that nearly one out of every three has changed his or her eating habits (30%) or sought out organically grown produce (32%) in the past year due to reports about pesticide and chemical use.

The majority (72%) of shoppers who changed their eating habits for this reason specifically sought out organically grown fruits and vegetables, according to the survey. Of all the shoppers polled, 64% had eaten organic fruits and vegetables; of those, 59% said the most important reason for buying organic produce was long-term health benefits, and 21% cited the nutritional value of the produce. Of shoppers who have never eaten organic produce, 77% said they would buy it if it cost the same as non-organic fruits and vegetables. The majority (68%) of shoppers surveyed think the federal government is doing a fair or poor job of protecting consumers from potentially harmful chemicals and pesticides in fruits and vegetables. For more information about the survey, contact Robert Martin, Rodale Press, Inc., 33 E. Minor St., Emmaus, PA 18098; (610)967-7588.

Guide for authors

The American Journal of Alternative Agriculture (AJAA) publishes original research on biological, physical, or social science aspects of alternative agriculture. We particularly welcome multi-disciplinary studies, but papers from a specific discipline also are invited. However, since AJAA readership is much broader than for a single-discipline journal, highly specialized terminology should be explained or avoided. The significance of a statement, or the reasoning behind a conclusion, may have to be spelled out more than in a more specialized journal. See Vol. 5, No. 1, pp 2 & 3, for an explanation of the various categories of articles.

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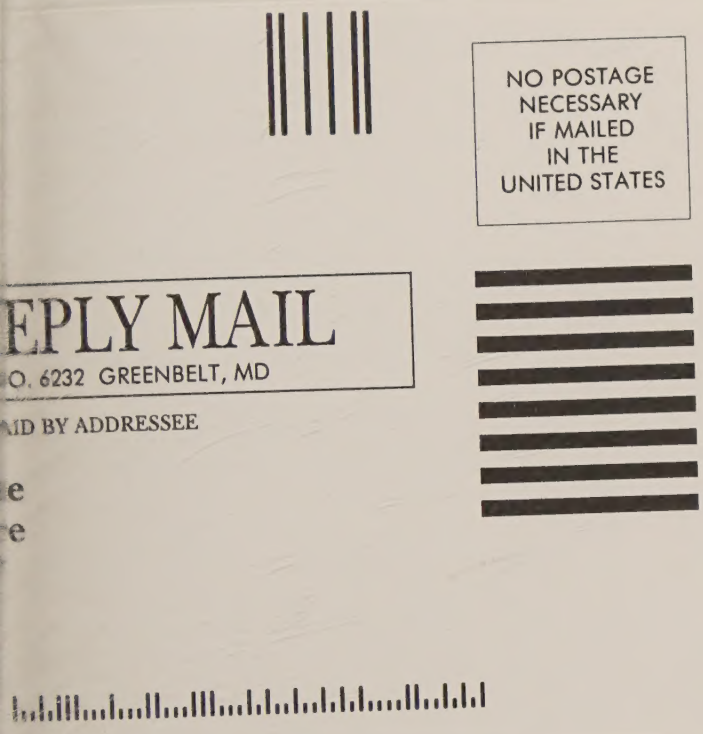

Provide subject matter key words suitable for use in scientific indexing.

Reference list

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Use full names of journals, institutions, conferences, etc., except for extremely familiar abbreviations like "Dept." Remember that an abbreviation familiar to you may not be familiar to readers outside your field. If in doubt, write it out.

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Cite references in the text by last name and year, with chapter or page numbers if the reference is a book or lengthy report. For two authors, give both names. Do not use "et al." unless there are at least three authors.

Footnotes

AJAA does not use bibliographic or substantive footnotes. All bibliographic references should be at the end of the text. Instead of substantive footnotes, include the material in the main text or consider eliminating it.

Manuscript preparation

The entire manuscript, including abstract and references, should be typed on one side of standard-size paper, double spaced, with margins of at least one inch all around. Starting with the title page, label all pages in the upper righthand corner with the lead author's last name and the page number. Do not use hyphens unless the hyphen is part of the word.

Follow the section headings style used in this AJAA issue. All headings are flush left, with no underlining or italics.

Tables should fit on one page, be numbered consecutively with Arabic numerals, and be on a separate sheet. Leave extra space to separate columns. Every figure and table should be mentioned at least once in the text.

Submission of manuscripts

Submit four high-quality copies to Editor, American Journal of Alternative Agriculture, Suite 117, 9200 Edmonston Road, Greenbelt, MD 20770. The cover letter should state that the manuscript is an original contribution that has not been published elsewhere in substantially the same form; that it is not currently under consideration elsewhere, and that permission has been obtained for any copyrighted material used.

How you can help support the scientific and educational needs of a sustainable agricultural system

A growing number of Americans have become concerned about the long-term sustainability of our food production system. Farmers and agricultural scientists are among those raising questions about the growing dependence of modern farming on nonrenewable resources, the depletion of our resource base through soil erosion, and heavy reliance on chemical fertilizers and pesticides. Continued heavy reliance on farm chemicals is questioned because they have become an expensive production input. Their widespread use also raises questions about human and animal health, food quality and safety, environmental quality, and the continued demise of the family farm.

Low-input alternative farming methods address these economic and environmental challenges. Alternative production systems point the way toward more profits, more individual choice, and long-term sustainability for our food system. More must be done to develop effective ways to make sure research, education, and information sources are readily available to farmers who want to adopt these techniques.

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